Eastern South Dakota Soil and Water Research Farm

1994

Annual Report to the Board of Directors

USDA, ARS, Brookings SD
USDA, ARS, Morris MN
South Dakota State University

Annual Report

Eastern South Dakota Soil and Water Research Farm

Volume 6, March 1995

Eastern South Dakota Soil and Water Research Farm, Inc.
Board of Directors

Brookings Research Farm Planning Committee

List of Participants

North Central Soil Conservation Research Laboratory, ARS, Morris, MN

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Dr. Frank Forcella, Research Agronomist
Dr. Michael J. Lindstrom, Soil Scientist
Dr. Donald C. Reicosky, Soil Scientist
Mr. Peter E. Stegenga, Agricultural Research Technician (Retired 12/94)

Northern Grain Insects Research Laboratory, ARS, Brookings, SD

Dr. Laurence D. Chandler, Research Leader
Dr. Michael M. Ellsbury, Research Entomologist
Dr. Robert W. Kieckhefer, Research Entomologist
Dr. Walter E. Riedell, Research Plant Physiologist
Dr. W. David Woodson, Research Entomologist
Mr. Max Pravecek, Biological Technician

South Dakota State University, Brookings, SD

Dr. Thomas E. Schumacher, Professor, Plant Science
Dr. Sharon Clay, Assoc. Professor, Plant Science
Dr. David Clay, Asst. Professor, Plant Science
Dr. Kevin Kephart, Assoc. Professor, Plant Science

History of the Eastern South Dakota Soil and Water Research Farm

The Eastern South Dakota Soil and Water Research Farm, Inc. is a non-profit organization consisting of a Board of Directors elected from each of 15 Soil and Water Conservation Districts in eastern South Dakota: Brookings, Codington, Clark, Day, Deuel, Hamlin, Kingsbury, Lake, Lincoln, Marshall, McCook, Minnehaha, Minor, Moody, and Turner. The purpose of the corporation is to promote research of efficient farm production practices that conserve soil and water resources.

The corporation bought 100 acres of land in Lake County, South Dakota, near the community of Madison in 1959. This land was leased to the Agricultural Research Service, United States Department of Agriculture. The work performed at the Madison farm included evaluation of the erosion of different soil types, development of tillage practices to conserve soil and water; determination of efficient crop production methods; and modeling plant-insect interactions. Research was conducted by scientists from the North Central Soil and Water Conservation Laboratory, ARS, Morris, MN; the Northern Grain Insects Research Laboratory, ARS, Brookings, SD; and the South Dakota Agricultural Experiment Station.

The Board of Directors decided to relocate the research farm closer to the research laboratories to improve program efficiency and facilitate productive cooperative research programs that would more effectively solve some of the problems that are associated with agriculture in eastern South Dakota. The Madison research farm was sold in 1987, and the Corporation bought another tract of land in Brookings County.

The Brookings research farm consists of 80 acres located approximately one mile north of the campus of South Dakota State University. The soils found on this farm are characteristic of those found in northeastern South Dakota and west central Minnesota and are similar to soils common to the northern corn belt.

Research Prospectus

Safety of ground water from chemical contamination and the long-term economic viability and environmental compatibility of agricultural production practices in the foremost concern of the public, farmers, and the scientific community. The widespread use of fertilizers and pesticides for agricultural production poses several significant and interdependent problems. Agricultural chemical contamination of ground water supplies ha the potential for catastrophic impact upon human health, wildlife, and the environment. The high energy and economic costs associated with the production and use of fertilizers and pesticides may cause conventional crop production practices which rely on high levels of chemical inputs to become economically unfeasible in the near future. The deleterious environmental and economic consequences of conventional high-input farming practices are threatening the future of the family farm and rural communities. This sociological and economic upheaval will undoubtedly worsen if we continue along our current course.

The problems outlined above are complex, and therefore have no simple solution. No single scientific discipline can adequately address these problems in a manner that will achieve effective solutions. Rather, scientists representing many disciplines will need to join forces and focus simultaneously on these problems with the goal of finding acceptable solutions. This research farm provides the impetus and the opportunity for the scientific personnel from South Dakota State University and the Agricultural Research Service to address the complex problem outlined above. A research program that integrates many scientific disciplines from the various institutions is truly a meaningful way to focus on the complex ground water quality and sustainable agriculture issue.

1994 CROP REPORT

Max Pravecek
USDA, ARS Northern Grain Insects Research Laboratory

The 1994 Input Plot growing season saw:

Dr. Sharon Clay (SDSU) and Dr. Frank Forcella (USDA, Morris) monitor weed populations, Dr. Bob Kieckhefer (USDA, Brookings) monitor insect populations in wheat, alfalfa, and grass plots, Dr. Dave Woodson (USDA, Brookings) monitor adult corn rootworm emergence, Dr. Kevin Kephart (SDSU) monitor grass plots, Dr. Mike Ellsbury (USDA, Brookings) monitor ground beetle populations. Dr. Walter Riedell (USDA, Brookings) did tissue analysis of corn, soybean, and wheat plants for nutrient value.

Experiments not conducted on the input plots were done by Dr. Mike Lindstrom (Morris) and Dr. Tom Schumacher (SDSU), compaction of soil in different tillages, Dr. Larry Chandler (Brookings), spray techniques of corn rootworm adult bait, Dr. Walt Riedell (Brookings), tillage and fertilizer experiment, and Ron Vos (SDSU),medic as a cover crop in corn.

An analysis of yield data was done using GLM SAS program for analysis of unbalanced data ($P<0.05$).

Alfalfa yields for high, integrated, and low input plots were all statistically different. Wheat yields were greatest for high input and least for low input and all were statistically different.

Soybean yields were similar in the Corn/Soybean and Four Year rotation but both were statistically different than the Corn/Soybean on ridges rotation.

For the corn crop, mean corn yields for the three input levels show best yields for high input and worst for low input. Mean corn yields for Continuous Corn, Corn/Soybean, Corn/Soybean on ridges, and Four Year rotations show highest yield for the Four Year rotation. Corn/Soybean less than the Four Year rotation but greater than Corn/Soybean on ridges and Continuous Corn rotations. Corn/Soybean on ridges and Continuous Corn rotation were the same. Low input in the Continuous Corn rotation produced no yield at all.

The following tables show yield for all crops and statistical differences in inputs and rotations.

1994 Mean Corn Yield
Bu./Acre

	Continuous Corn	Corn/ Soybean	Corn/Soybean on Ridges	Four Year	Mean Input Yield
Input					
High	134.8 a,x	144.4 a,x	135.5 a,x	136.0 a,x	137.8
Int.	70.1 b,x	111.9 b,y	74.4 b,x	118.9 a,y	93.8
Low	0.0 c,x	34.3 c,y	31.7 c,y	90.1 b,z	39.0
Rotation Mean Yield	68.3	96.9	80.5	115.2	

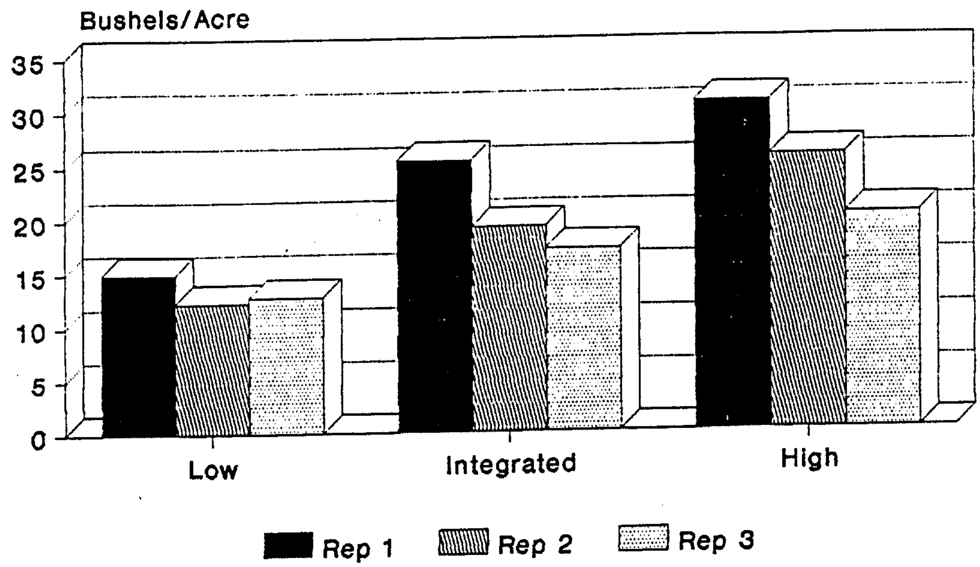
1994 Mean Soybean Yield
Bu./Acre

	Soybean/Corn	Soybean/Corn on Ridges	Four Year	Mean Input Yield
Input				
High	42.7 a,x	40.1 a,x	41.2 a,x	41.3
Int.	25.3 b,x	21.9 b,x	27.2 b,x	24.8
Low	21.7 b,x	15.7 c,y	28.3 b,z	17.3
Rotation Mean Yield	29.9	25.9	32.2	

	1994 Mean Wheat Yield Bu./Acre Four Year Rotation	**1994 Mean Alfalfa Yield** Tons/Acre Four Year Rotation
Input		
High	25.5 a*	3.5 a
Int.	20.6 b*	2.8 b
Low	13.4 c	2.2 c

Means in columns followed by a, b, or c are significantly different at P = 0.05.
Means in rows followed by x, y, or z are significantly different at P = 0.05.
Four Year rotation is corn/soybean/wheat/alfalfa cropping system.
*P = 0.057

1994 Wheat Yield
4 Year Rotation



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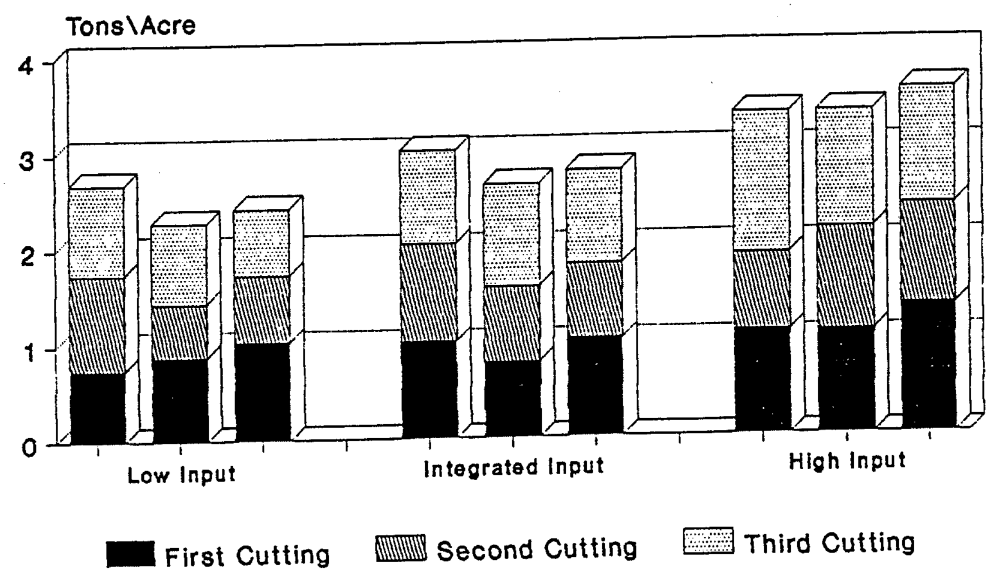
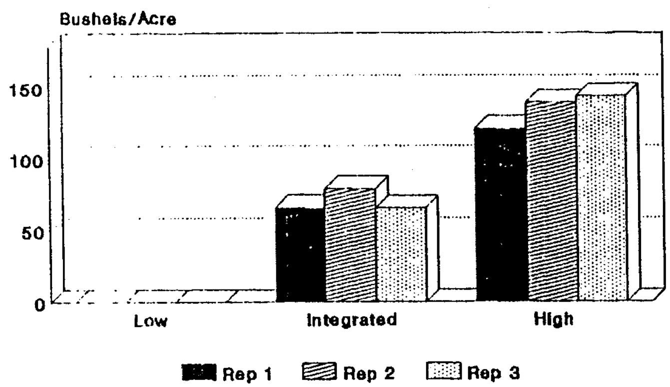
1994 Legume Yield
4 Year Rotation



USDA Research Farm

1994 Corn Yield
Continuous Corn



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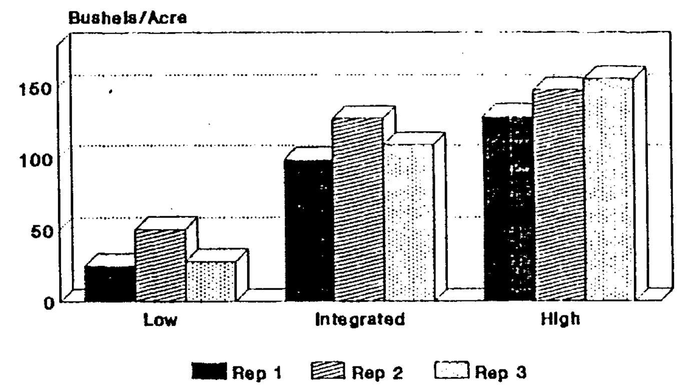
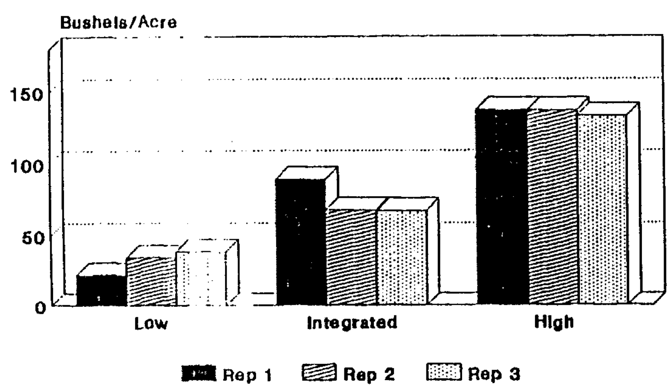
1994 Corn Yield
Corn Soybean Rotation



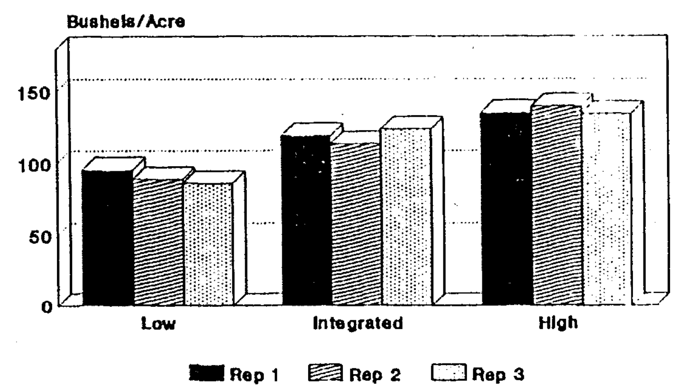
USDA Research Farm

1994 Corn Yield
Corn Soybean Rotation on Ridges



USDA Research Farm

1994 Corn Yield
4 Year Rotation



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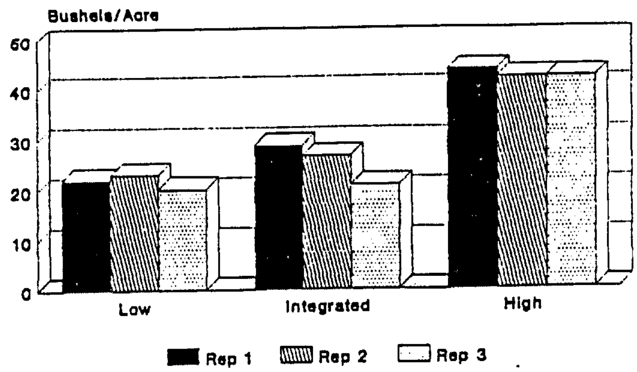
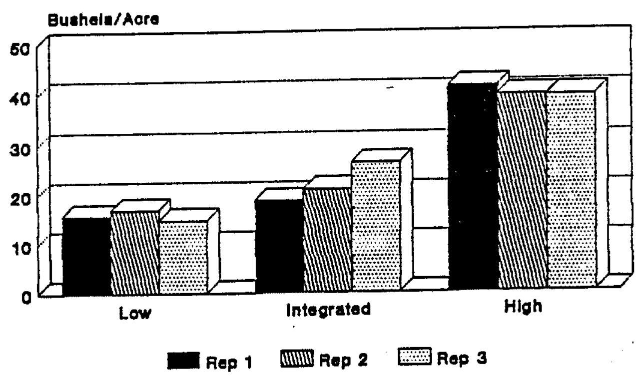
1994 Soybean Yield
Corn Soybean Rotation



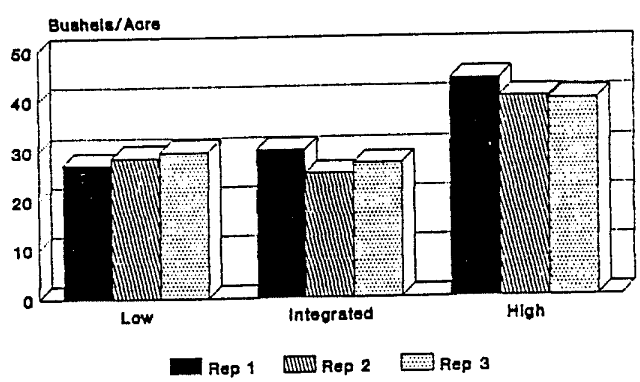
USDA Research Farm

1994 Soybean Yield
Corn Soybean Rotation on Ridges

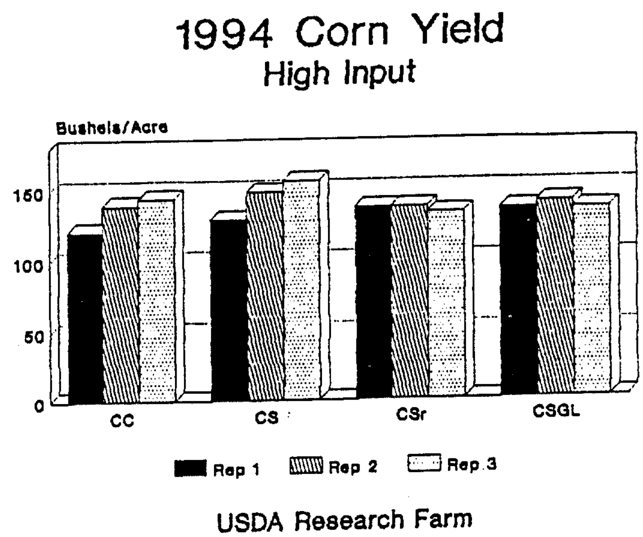


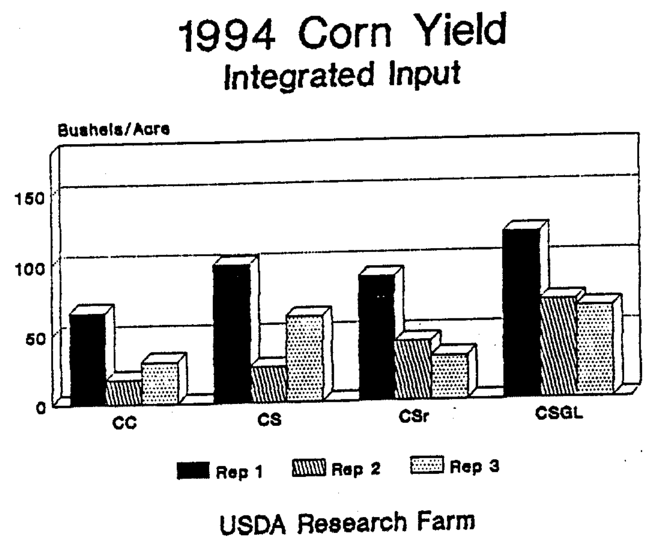
USDA Research Farm

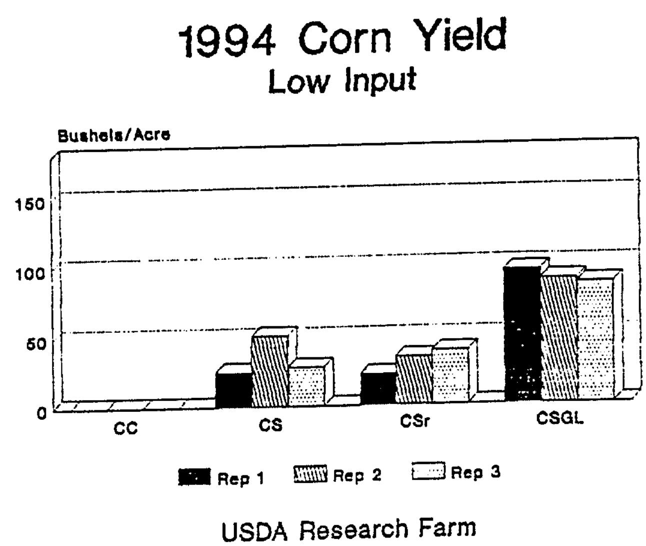
1994 Soybean Yield
4 Year Rotation



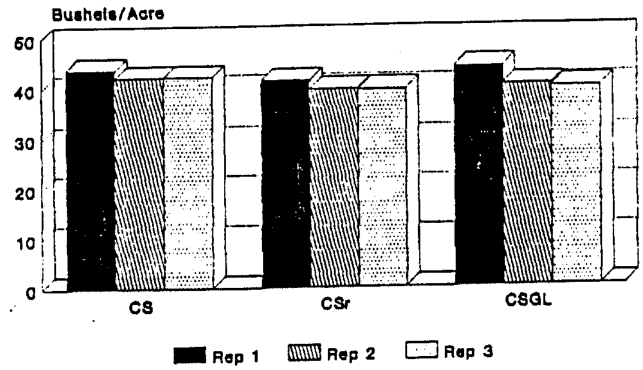
USDA Research Farm


1994 Corn Yield
High Input
Bushels/Acre
150
100
50
0
CC
CS
CSr
CSGL
Rep 1
Rep 2
Rep 3
USDA Research Farm


1994 Corn Yield
Integrated Input
Bushels/Acre
150
100
50
0
CC
CS
CSr
CSGL
Rep 1
Rep 2
Rep 3
USDA Research Farm

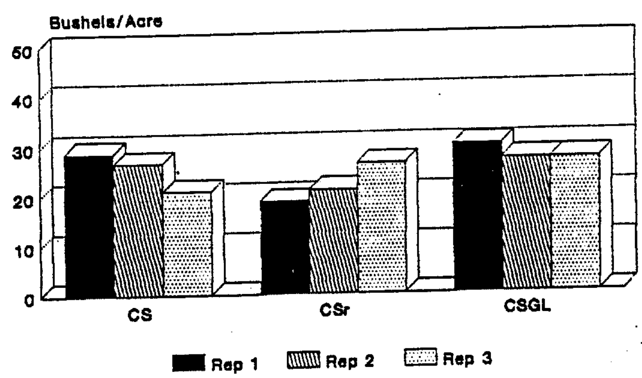

1994 Corn Yield
Low Input
Bushels/Acre
150
100
50
0
CC
CS
CSr
CSGL
Rep 1
Rep 2
Rep 3
USDA Research Farm

1994 Soybean Yield
High Input



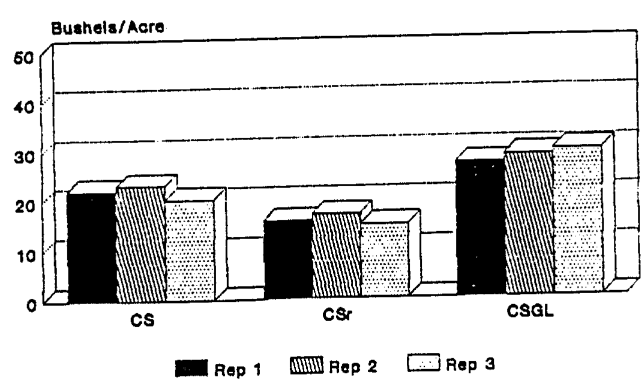
USDA Research Farm

1994 Soybean Yield
Integrated Input



USDA Research Farm

1994 Soybean Yield
Low Input



USDA Research Farm

CROP ROTATION AS A COMPONENT OF SUSTAINABLE AGRICULTURAL SYSTEMS

Walt Riedell
USDA, ARS Northern Grain Insects Research Laboratory

and

Tom Schumacher
Plant Science Department, South Dakota State University

Toward a new vision for agriculture

The accomplishments of modern agriculture are many and great. Farmers the world over have removed the threat of chronic starvation for most of the world's population. The ability to feed the world was the result of a concerted effort by fertilizer, seed, and agrochemical industries coupled with farm machinery manufacturers, farmers, and the educational/extension system to develop a technology-based agriculture system. Through the use of chemical fertilizers and pesticides, larger and more efficient farming equipment, and highly productive crop varieties, fewer farmers are producing greater amounts of food than ever before.

The development and widespread adoption of the technology-based agriculture systems happened rapidly after the second world war. Probably the most influential reasons for this rapid adoption to a technology-based agriculture was that it worked: the systems were simple, stood alone, were backed up by an extensive experimental base, and were easily communicated. The result of this new marriage between technology and agriculture was a clearly-visible increase in productivity which benefited not only the farmer, but also the industries that supplied the technology. The technology-based agriculture quickly became "conventional".

The widespread use of conventional agriculture systems was coupled with an increase in farm size, a consolidation of land ownership to fewer individuals, and the purchase of large amounts of off-farm inputs. Economic upheaval during the 1980's, spurred by dropping farm land prices and increased farm debt to asset rations, caused even more farmers to go out of business. Many of the farmers that survived the economic upheaval of the 1980's began to look for ways to cut their input costs while still maintaining or increasing their production efficiency.

Coupled with these economic upheavals was a new awareness of the environmental costs of the conventional agriculture. Soil erosion from wind and water, agriculture chemical contamination of surface and ground water resources, and pesticide residues in food became important issues for discussion by the farm community as well as the urban community. The need to increase farming efficiency to feed increasing world population, the loss of prime agricultural lands due to encroachment by urban areas, loss of soil productivity due to erosion, and floods resulting from sediment build-up in downstream areas are problems that will continue to plague society well into the next century. Contamination of ground and surface waters by agricultural chemicals poses a serious health threat to any living organism, including humans, that uses that water source. Pesticide residues in food could pose insidious health threats to the consumer. (for further information, please read "Sustainable Agriculture Systems" edited by J.L. Hatfield and D. L. Karlen and published by Lewis Publishers, Boca Raton)

Sustainable agriculture can be defined as the effective and productive use of natural resources so that they are conserved or enhanced while still producing commodities. A basic tenet of sustainable agriculture is that the crop production systems used must be economically viable. One way to ensure economic viability is to exchange the agricultural chemical dependency syndrome of "maximum yield" for the sustainable agriculture trait of "maximum profitability" in an environmentally responsible manner. Substitution of knowledge-based crop management protocols for conventional high-input production practices would achieve maximum profitability by optimizing use of off farm inputs.

There are also other important advantages of sustainable agriculture systems besides maximum profitability. These include maintenance of an optimal physical environment for topsoil nutrient availability, increased water infiltration into the root zone, increased ability of the soil to buffer short term environmental changes, and minimized contamination of surface and ground water. All of these advantages are inter-related and dependent at least in part on soil physical properties, soil organic matter levels, and soil-plant nutrient relations.

The use of crop rotation as a substitute for fertilizer and pesticide inputs would go a long way in enhancing the sustainable nature of in agriculture production systems used in eastern South Dakota and western Minnesota, and would enhance within this region the environmental and natural resource base upon which a sustainable agricultural economy depends. A more thorough and complete understanding of how crop rotations affect crop growth and yield, with particular emphasis upon crop mineral nutrient relations, is needed as a base for measuring the economic feasibility of using crop rotations in sustainable agricultural systems.

All of these concerns indicate a need for research, demonstration, and adoption by farmers of different ways to farm that conserve our soil and water resources, and reduce pesticide usage. The research conducted at the Eastern South Dakota Soil and Water Research Farm, and the demonstration of that research to farmers is a step towards answering that need.

Growing crops without chemical inputs: Productivity of crop rotations

Considerable information exists about crop rotations and their impact on crop productivity. Two of the main conclusions drawn from this information are 1) Rotations that include nitrogen-fixing legumes reduce the amount of applied nitrogen needed for optimum yield in the non-legume crops; 2) Crop rotation decreases weed populations. This information should be good news to the farmers of South Dakota, who, in 1991 used almost 170,000 tons of actual N fertilizer and applied herbicide to 92 % of the corn acres, 95 % of the soybean acres, and 74 % of the spring wheat acres. The question is, however, what crop rotations will work best in eastern South Dakota?

To answer this question, three crop rotations (continuous corn, a two-year corn/soybean rotation, and a four year corn/soybean/wheat/alfalfa rotation) were established at the Eastern South Dakota Soil and Water Research Farm in 1990. Each rotation was grown under 3 different input levels:
High inputs = soil test-based fertilizer application for 130 bu / acre yield goal, pre-emergence and post-emergence herbicide and insecticide applied whether needed or not.
Conventional inputs = soil test-based fertilizer application for 85 bu / acre yield goal, pre- or post-emergence herbicide and insecticide applied only as needed.
No chemical inputs = no fertilizer application, weed control through cultivation only, no insecticide.

Five year yield averages for the corn, soybean, wheat, and alfalfa crops grown under the different rotations and input levels are given in Table 1. The high input corn yields were very similar across all rotation treatments studied. The corn/soybean and corn/soybean/wheat/alfalfa rotations produced considerably higher yields than the continuous corn rotation under the conventional and no input levels. Figures 1 though 3 show yield results for the crop rotation - input level experiments throughout the five years of the experiment. Corn yields were depressed during the 1992 ("the year without summer") and 1993 ("the year of the flood") growing seasons in all of the rotation/input level treatments. It is interesting to note that the yields of the continuous corn and corn / soybean rotations under the no input treatment dropped precipitously to near zero during the first three years of the experiment. Corn yields in these plots did not recover in the 1994 field season.

Soybean yields in the corn/soybean and corn/soybean/wheat/alfalfa rotations were very similar within the high and conventional input treatments (Table 1). The soybean yield for the corn/soybean/wheat/alfalfa rotation was slightly higher than the corn/soybean rotation in the no input treatment. Figures 2 and 3 reveal that soybean yields were much more stable across the various growing season environments seen during the duration of the experiment. Wheat yields in the corn/soybean/wheat/alfalfa rotation were higher in the high and conventional input treatments than in the no input treatment (Table 1). The no input wheat did not show the yield "spike" that the other input level treatments showed in 1992 (Fig. 3).

Soil and plant nitrogen relationships in the rotation/input plots

The ecological interpretation of the "nitrogen cycle" is based upon understanding the idealized flow of N from soil to crops and animals and back to the soil again (with additional flows to and from the environment). In the past, studies of the agricultural nitrogen cycle concentrated upon single farms. This approach was appropriate because, prior to World War II, crop and animal production usually took place on the same farm and therefore the nitrogen cycle was contained within the farm boundary. After World War II, however, N fertilizer production and use increased dramatically (due to a conversion from using N for manufacturing munitions to using N for manufacturing fertilizer). Cheap and available N fertilizer and the development of highly productive hybrid corn varieties shifted the nitrogen cycle from the local farming system to large-scale transfers of N from fertilizer manufacturing plants to farms and farm land. Consequently, nitrogen became an input to farms from business and industry. With this change in the nitrogen cycle came the need to increase the scope of agriculture nitrogen cycle studies to include an understanding of the nitrogen pathways at the ecosystem level. (for further information on this subject, please read "Does Nitrogen Cycle" by L.E. Lanyon, pages 70 to 78 in the *Journal of Production Agriculture*, Volume 8, 1995)

About 75 million pounds of nitrogen are found in the atmosphere above every acre of land and sea on earth. Using large amounts of fossil fuel energy, chemists are able to "fix" atmospheric nitrogen into fertilizer forms. Certain bacteria, such as those in nodules of legume roots, are also able to fix atmospheric nitrogen. This fixed nitrogen is then incorporated by the developing plant into amino acids and proteins. At the end of the growing season, when the grain is harvested and the crop residue remains in the field, this stover contains nitrogen that, when released by stover decay during the next growing season, improves soil fertility.

Nitrogen often occurs in the soil at concentrations below those necessary for optimum corn yield production. Currently, profitable farming depends largely upon a supply of nitrogen in the form of fertilizers. Corn producers applied nitrogen fertilizer to 84 percent of the South Dakota corn acreage in 1992 at an average rate of 57 pounds of nitrogen per acre. Restoring organic matter to the soil in order that, through decay, it may furnish a revolving supply of nitrogen for crops is a crop production alternative to fertilizer application.

Can rotations with crops that fix nitrogen be used to augment fertilizer nitrogen inputs for economically-viable sustainable agricultural enterprise?

Nitrogen is needed by the corn plant throughout the growing season, however, it is needed in the greatest quantity during the period of most rapid reproductive plant growth which extends about 2 weeks before tassel until 3 weeks after tassel. The June 20, 1994 soil test results reveal that at the beginning of this rapid reproductive plant growth period (the V-6 to V-7 stage of corn growth), the rotation which included alfalfa had the highest levels of soil nitrate-N, while the corn/soybean rotation had about half that level. The continuous corn rotation showed the lowest nitrate-N soil levels. Generally speaking, the nitrate-N levels at this sample date were higher in the conventional input treatments than in the no input treatments. Taken together, these results indicate that fertilizer application can increase soil nitrate-N levels immediately before the time of greatest plant demand. However, the rotation that contained alfalfa did the best job of providing soil nitrate-N at this critical time period.

Table 2 shows nitrate-nitrogen soil test levels for a pre-season test (April 19, 1994) as well as a test conducted when the corn plants were at the V-6 to V-7 stage of development (June 20, 1994) and again at the end of the growing season (September 29, 1994). Soil test N levels taken during the pre-season were generally highest in the rotation that included alfalfa, and next highest in the corn/soybean rotation. At the end of the season, the soil N levels were highest in the corn/soybean/wheat/alfalfa rotation plots under the high and conventional input treatments. The N level seen in the no input corn/soybean/wheat/alfalfa rotation plots was similar in to those N levels seen in the high and conventional input levels in the continuous corn and corn/soybean rotations. The N level seen in the no input continuous corn plots was the lowest of all plots.

Plant dry weights, plant N uptake, and grain yields for the 1994 growing season were generally highest in the high input treatments and slightly lower in the conventional inputs treatments (Table 3). Of interest is the good yield performance of the no input corn/soybean/wheat/alfalfa rotation, which had higher yields than the conventional input continuous corn rotation as well as the no input continuous corn and corn/soybean rotation treatments. Economic analysis of these rotation/input plots would be useful in determining which of these treatments would be most profitable.

Preseason soil test N levels, crop rotation N credits, and realistic yield goals form the basis of a logical design of crop N fertilizer inputs. The N fertilizer balance sheet for the 1994 growing season is shown in Table 4. Currently, SDSU soil testing laboratory recommendations include a 1 lb nitrogen credit for each bushel of soybeans produced the previous year, as well as 100 lbs nitrogen credit for legume sods at 3 or more plants per square foot. Using these criteria, it is possible to show whether plots were over-fertilized or under-fertilized with N. The N fertilizer treatments that came closest to the actual crop needs based on yield goals were the high input continuous corn (which was over-fertilized by 10 lbs N per acre), the conventional input corn/soybean rotation (which was over-fertilized by 16 lbs N per acre), and the no input corn/soybean/wheat/alfalfa rotation (which had 27 lbs N per acre greater than the crop needs).

We were interested in measuring the potential impact of these N treatments and crop rotations on potential nitrate contamination of groundwater resources. A computer model entitled NLEAP (<u>N</u>itrogen <u>L</u>eaching and <u>E</u>conomic <u>A</u>nalysis <u>P</u>ackage, developed by M.J. Schaffer-ARS, Fort Collins CO; A.D. Halvorson-ARS, Akron CO; and F.J. Pierce, MSU, East Lancing, MI) was used to evaluate the amount of nitrogen available for leaching into the ground water. The type of information needed to drive the model are: soil classification (soil type, landscape position, preseason nitrate levels), weather data (rainfall and temperature-provided by data base), previous crops data (previous and current crop type, yield, residue remaining), tillage operations (tillage type and timing), fertilizer application (fertilizer production, method and timing of application), and aquifer characteristics (aquifer depth and movement). After plugging this information into the model, a model determined of the amount of nitrogen leached into the aquifer (in lbs N per acre per year). These results are presented in Table 5. In a year with average rainfall, the model predicts that the amount of nitrogen leached in the continuous corn and corn/soybean rotations was almost twice as high as corn/soybean/wheat/alfalfa rotation. These values remained consistent for a year with high rainfall. (For further information about NLEAP, please read "Managing Nitrogen for Groundwater Quality and Farm Profitability", edited by R.F. Follett, D.R. Keeney, and R.M. Cruse; published by the Soil Science Society of America, Inc., Madison WI).

These results, while interesting, discuss only the soil nutrient and plant productivity aspects of the rotation/input research. Please consult the other annual reports on weeds and insects to obtain a holistic understanding of the rotation/input research conducted at Eastern South Dakota Soil and Water Research Farm.

All of the research mentioned above represents cooperative investigations of the USDA Agricultural Research Service and the South Dakota Agricultural Experiment Station.

Summary

ARS and South Dakota State University scientists demonstrated during the 1994 growing season that a 4-year crop rotation produced a relatively high grain yield without the use of chemical (herbicide, insecticide, or fertilizer) inputs. The 4-year rotation (consisting of a crop sequence of corn/soybean/wheat inter-seeded with alfalfa/alfalfa), which used cultivation for weed management but otherwise had no chemical inputs, yielded 90 bushels of corn per acre. In comparison, a 2-year corn/soybean rotation with no chemical input yielded only 34 bushes of corn per acre while a corn following corn rotation had no grain yield at all. Scientists attribute the better comparative performance of the 4-year rotation in part to greater soil nutrient levels (particularly nitrogen). This research was conducted at the Eastern South Dakota Soil and Water Research Farm, a non-profit organization that promotes research of efficient farm production practices that conserve soil and water resources.

TABLE 1. Five year yield averages for crops grown at the Eastern South Dakota Soil and Water Research Farm

	Rotation		
	Continuous Corn	Corn/Soybean	Corn/Soybean/Wheat/Alfalfa
	Corn Yield (Bu/Acre)		
Input Level			
High	115	121	121
Conventional	85	104	106
No	36	50	88
	Soybean Yield (Bu/Acre)		
High	--	36	34
Conventional	--	28	29
No	--	21	25
	Wheat Yield (Bu/Acre)		
High	--	--	26
Conventional	--	--	22
No	--	--	15

Input levels defined as: High Inputs = soil test based fertilizer application for 130 bu/acre yield goal, and prophylactic herbicide and insecticide treatments; Conv. Inputs = soil test based fertilizer application for a 85 bu/acre yield goal, and herbicide and pesticide used only as needed; No Inputs - no chemical inputs, no fertilizer application, weed control through cultivation only, no insecticide.

TABLE 2. Soil test results[1] for rotation plots at the Eastern South Dakota Soil and Water Research Farm at 3 dates in 1994.

	April 19, 1994		June 30, 1994		September 29, 1994	
	Top N	Total N	Top N	Total N	Top N	Total N
Input Level[2]	Lbs/Acre					
	Corn/Soybean Rotation					
High Inputs	30 ± 5	38 ± 5	23 ± 5	35 ± 7	18 ± 6	38 ± 17
Conv. Inputs	22 ± 5	28 ± 6	22 ± 1	34 ± 1	15 ± 0.3	32 ± 10
No Inputs	24 ± 5	30 ± 5	23 ± 2	35 ± 4	9 ± 1	21 ± 9
	Continuous Corn					
High Inputs	24 ± 11	32 ± 14	21 ± 1	31 ± 2	14 ± 3	31 ± 10
Conv. Inputs	21 ± 4	27 ± 4	15 ± 2	23 ± 3	8 ± 1	27 ± 7
No Inputs	17 ± 2	21 ± 2	15 ± 3	21 ± 4	6 ± 0.2	9 ± 0.3
	Corn/Soybean/Wheat/Alfalfa Rotation					
High Inputs	35 ± 13	44 ± 13	38 ± 1	58 ± 3	18 ± 5	45 ± 10
Conv. Inputs	41 ± 9	49 ± 8	38 ± 5	65 ± 13	19 ± 4	51 ± 16
No Inputs	27 ± 4	29 ± 2	32 ± 2	50 ± 3	17 ± 2	26 ± 3
	Grass					
No Inputs	2 ± 0.3	3 ± 0.2	6 ± 0.3	8 ± 0.3	2 ± 0.5	14 ± 10

1 Soil test results obtained from the Soil Testing Laboratory at SDSU. Top N value represents mean (± standard error) level of nitrate-nitrogen for the top 8 inches of the soil profile. Total N values represent nitrate-nitrogen for the top 12 inches of the soil profile.

2 Input levels defined as: High Inputs = soil test based fertilizer application for 130 bu/acre yield goal, and prophylactic herbicide and insecticide treatments; Conv. Inputs = soil test based fertilizer application for a 85 bu/acre yield goal, and herbicide and pesticide used only as needed; No Inputs = no chemical inputs, no fertilizer application, weed control through cultivation only, no insecticide.

TABLE 3. Corn crop growth, nitrogen content, and grain yield for the rotation plots at the Eastern South Dakota Soil and Water Research Farm in 1994.

Input Level	Crop Biomass Weight (at tassel)	Crop Nitrogen Content (at tassel)	Grain Yield
	Lbs/Acre		Bu/Acre
		Corn/Soybean Rotation	
High Input	4933 ± 401	83 ± 9	144 ± 8
Conv. Input	5831 ± 430	106 ± 8	112 ± 8
No Input	2429 ± 162	34 ± 3	34 ± 8
		Continuous Corn	
High Input	5261 ± 127	75 ± 3	135 ± 7
Conv. Input	4622 ± 135	64 ± 7	70 ± 4
No Input	1122 ± 416	14 ± 7	0
		Corn/Soybean/Wheat/Alfalfa Rotation	
High Input	6150 ± 285	108 ± 11	136 ± 2
Conv. Input	4587 ± 611	91 ± 8	119 ± 3
No Input	4612 ± 161	74 ± 5	90 ± 3

Input levels defined as: High Inputs = soil test based fertilizer application for 130 bu/acre yield goal, and prophylactic herbicide and insecticide treatments; Conv. Inputs = soil test based fertilizer application for a 85 bu/acre yield goal, and herbicide and pesticide used only as needed; No Inputs = no chemical inputs, no fertilizer application, weed control through cultivation only, no insecticide.

TABLE 4. Soil test results and N fertilizer rates for the rotation plots at the Eastern South Dakota Soil and Water Research Farm in 1994.

	Fertilizer Rate							
	Starter (5/10/94)	Cultivation (6/20/94)	Nitrate Soil Test Level 4/29/94	1993 Legume N Credit	Total N in System	1994 Yield Goal	1994 Crop N Needs (Based on Yield Goal)	Total N Minus Crop N Needs
Input Level		Lbs/Acre				Bu/Acre	Lbs/Acre	
				Corn/Soybean Rotation				
High Inputs	13	85	38	30	166	130	156	+10
Conv. Inputs	6	85	28	25	144	85	102	+42
No Inputs	0	0	30	19	49	85	102	-53
				Continuous Corn				
High Inputs	13	85	32	0	130	130	156	-26
Conv. Inputs	6	85	27	0	118	85	102	+16
No Inputs	0	0	21	0	21	85	102	-81
				Corn/Soybean/Wheat/Alfalfa				
High Inputs	13	43	44	100	200	130	156	+44
Conv. Inputs	6	43	49	100	198	85	102	+96
No Inputs	0	0	29	100	129	85	102	+27

Input levels defined as: High Inputs = soil test based fertilizer application for 130 bu/acre yield goal, and prophylactic herbicide and insecticide treatments; Conv. Inputs = soil test based fertilizer application for a 85 bu/acre yield goal, and herbicide and pesticide used only as needed; No Inputs = no chemical inputs, no fertilizer application, weed control through cultivation only, no insecticide.

TABLE 5. NLEAP "screening" analysis of rotational plots at the Eastern South Dakota Soil and Water Research Farm.

	Nitrogen Leached (lbs N $acre^{-1}$ $year^{-1}$)		
Rotation	Low PPT.	Average PPT.	High PPT.
Corn/Soybean			
M1[1]	0	0.9	16.6
M2	0	3.9	16.6
Continuous Corn			
M1	0	1.0	18.3
M2	0	4.1	18.3
Corn/Alfalfa			
M1	0	0	5.2
M2	0	1.8	10.1
Annual Leaching Risk Potential[2]	High	Very High	Very High

1 Crop uptake of N is treated as a data input (yield goal) and also is computed by the efficiency factor method. These methods produce corresponding values (M1 and M2, respectively.

2 ALRP, which seems to be highly related to aquifer characteristics, suggests operator undertake further analysis.

Figure 1. Continuous Corn

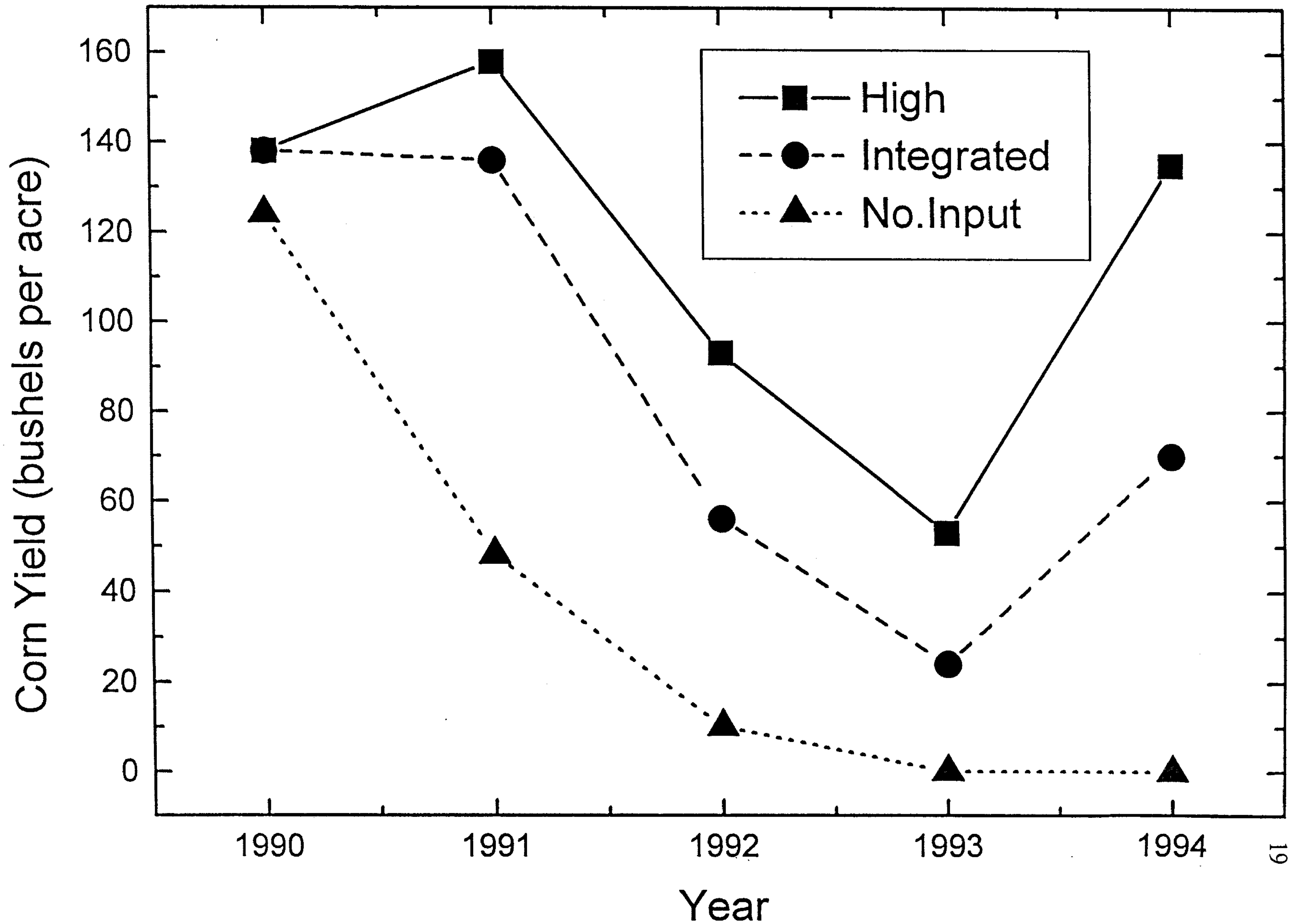


Figure 2. Corn Soybean Rotation

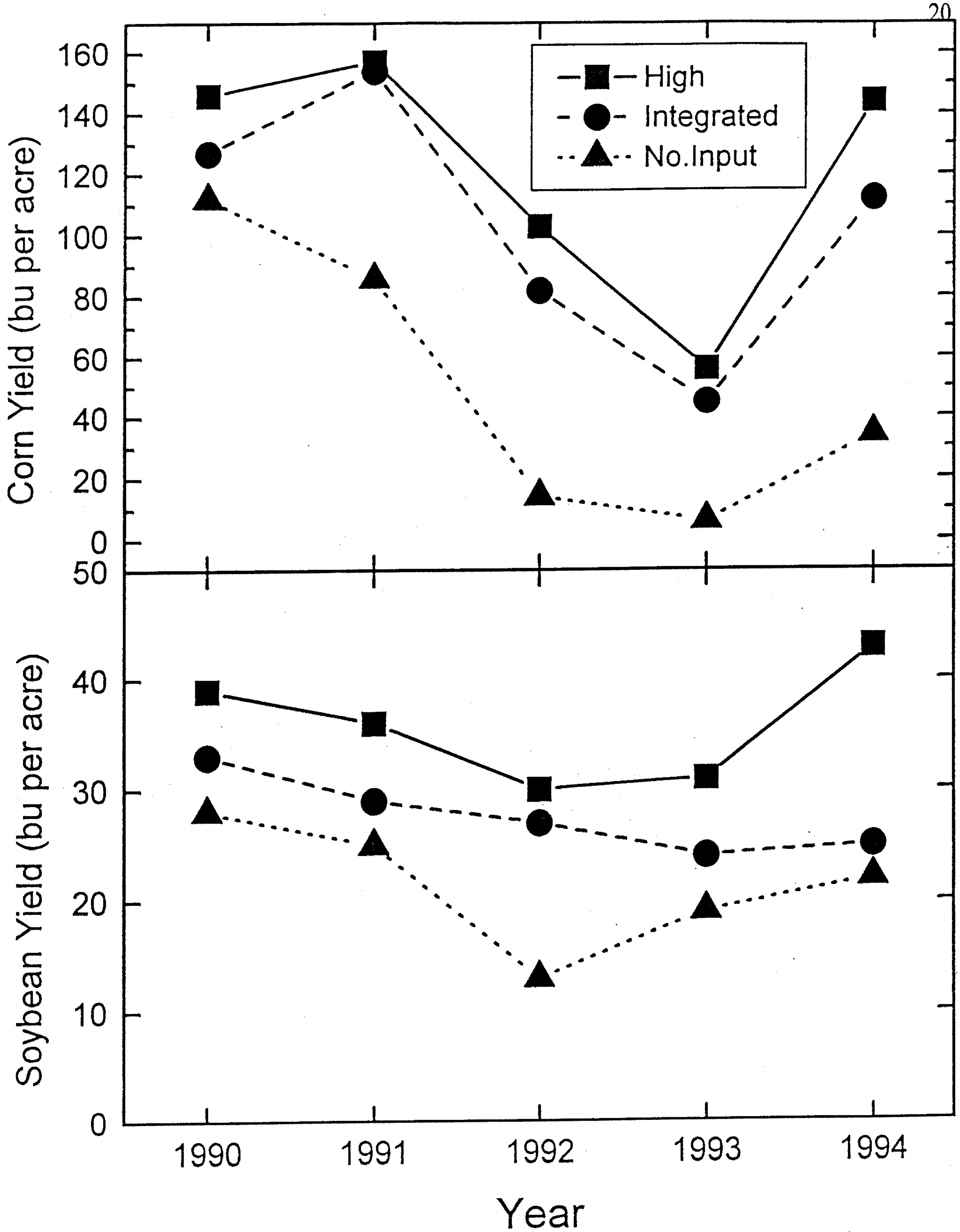
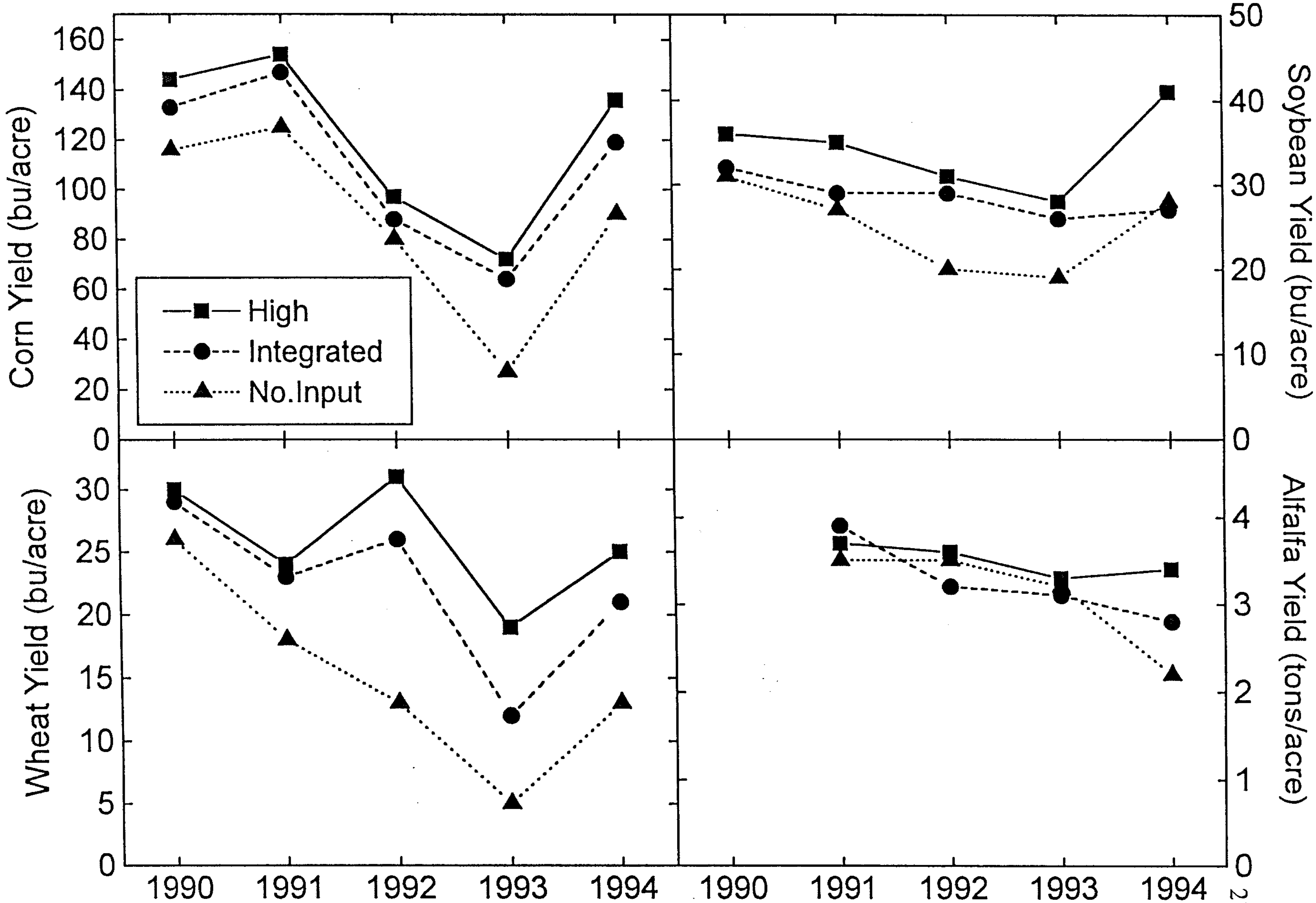


Figure 3. Corn/Soybean/Wheat/Alfalfa Rotation



INFLUENCE OF MANAGEMENT TREATMENTS IN VARIOUS CROPS ON THE ABUNDANCE AND DIVERSITY OF INSECT POPULATIONS

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Materials and Methods

Our research objective at the Eastern South Dakota Soil and Water Research Farm (ESDSWRF) is to determine the influence of management treatments (minimum input, integrated, and conventional) applied to the four-year rotation research plots on the abundance and diversity of insect populations in the aerial vegetation of these crops. Emphasis is on populations of the major economic insects of the crops. In this our fifth consecutive year of study on the ESDSWRF research plots, sampling continued to be carried out in wheat, alfalfa, and grass.

Insect populations were sampled by collecting two, 30-sweep, net subsamples from each of the nine 30.5 m x 30.5 m plots (three treatments - low, integrated and high input - each being replicated three times). A total of 18, 30-sweep, net subsamples were obtained from a crop type on a given sampling date. Insects in the samples were anesthetized using chloroform, transferred to containers, and frozen for later processing. When processing the samples, they were enumerated by taxon groups as outlined in Figure 1 (no dry weight biomass determinations made). The following taxa groupings were considered in all three crop types: common damsel bug, *Nabis americoferus*, common green lacewing, *Chrysoperla plorabunda*, and lady beetles (Coccinellidae). The developmental stage (adult versus larvae and/or nymph) was segregated for these taxa. The species of lady beetles were distinguished but for purposes of numerical data summary are lumped together. The wheat stem maggot, *Meromyza americana*, (adults only) was enumerated in both the wheat and grass. The potato leafhopper, *Empoasca fabae*, (adult and nymph combined) and alfalfa weevil, *Hypera postica*, (adult only) were only enumerated in alfalfa.

A "presence/absence method" was used in the field to obtain the data on aphids in wheat. Fifteen tillers (5 groups of 3 consecutive tillers) were examined per plot, and the data expressed as the percent of tillers infested with aphids. In alfalfa, aphid abundance was ascertained from the sweep net collection samples, however, a numerical rating scale was utilized instead of making an outright count as was done with all other taxa groups. Aphids were tallied in the grass plots for the first time in 1994. Since the occurrence of aphids in grass was relatively low, an actual count of individuals was made.

On 12 July 1994 a tally of wheat stem maggot "damage" (i.e. white heads) was done in the wheat. A count of damaged/white heads was made using a 0.09 m^2 quadrat (50 readings per plot); a count of the total number of wheat heads per quadrat (10 readings) was also made and the data expressed as the per cent of heads damaged.

Figure 1. Comprehensive listing of insect taxa enumerated from sweep net sample collections in 3 crop types, ESDSWRF, 1994.

Taxon	Developmental Stage	Crop Type: Wheat	Alfalfa	Grass
(PHYLUM ARTHROPODA/CLASS HEXAPODA):				
Order HEMIPTERA				
Family Nabidae - common damsel bug, *Nabis americoferus*	ad / ny [1]	X	X	X
Order HOMOPTERA				
Family Aphididae - aphids or plantlice	ad + ny	X	X	X
Family Cicadellidae - potato leafhopper, *Empoasca fabae*	ad + ny		X	
Order NEUROPTERA				
Family Chrysopidae - common green lacewing, *Chrysoperla plorabunda*	ad / la [1]	X	X	X
Order COLEOPTERA				
Family Coccinellidae - lady beetles [2]	ad/la/pu [1]	X	X	X
Family Curculionidae - alfalfa weevil, *Hypera postica*	ad		X	
Order DIPTERA				
Family Chloropidae - wheat stem maggot, *Meromyza americana*	ad	X		X

[1]Differentiate between developmental stages: ad = adult, la = larvae, pu = pupae, ny = nymph

[2]Distinguish among the various lady beetle species

Information on various kinds of vegetative parameters were collected and records of meteorological conditions were taken each time a crop was sampled for insects, but rather than re-elaborate here, the reader is referred to the 1991 ESDSWRF Annual Report for specific details on how this was done.

The 1994 chronology/phenology of sampling in each of the crop types was as follows:

Wheat - 28 June (watery-milk) = total of 1 sampling date
[wheat planted 13 April / harvested 4 August]

Alfalfa - 26 May (bud), 2 June (< 10% flowering), 12 July (> 10% - < 50% flowering), 15 August (bud), and, 7 September (> 10% - < 50% flowering) = total of 5 sampling dates
[1st cutting - 10 June, 2nd cutting - 18 July, 3rd cutting - 13 September]

Grass - 2 June, 16 August (Big Bluestem in anthesis), and, 8 September = total of 3 sampling dates

Results and Discussion

Inspection of the data from the insect population census in spring wheat, alfalfa, and grass plots at ESDSWRF during the 1994 growing season showed that six of the seven or eight species of lady beetles we have associated with the crops of the region were present in 1994. Only the convergent (*Hippodamia convergens*) and 13-spotted (*Hippodamia tredecimpunctata tibialis*) lady beetles were collected from wheat (Table 1); we detected no lady beetle reproduction in wheat, probably because of extremely low numbers of aphid prey (Table 2). The parenthesis (Hippodamia parenthesis) lady beetle was dominant in alfalfa; it and four other species of lady beetle reproduced in alfalfa in response to abundant pea aphids in that crop throughout another cool, moist, growing season. The transverse (*Coccinella transversoguttata richardsoni*) lady beetle was not collected from the plots this year; its numbers have been in decline coincident with the invasion of the seven-spotted (*Coccinella septempunctata*) lady beetle, which was introduced from Europe and is now well established here. Three native species of lady beetles were represented in the grass plots.

The abnormally cool, wet, 1994 growing season, like those of 1992 and 1993, retarded insect development and inhibited flight activity. Perhaps because of the general suppression of insect populations in field plots, we didn't observe significant differences in insect numbers that could be related to the management levels of the plots (Tables 3, 4, 5). Potato leafhopper (*Empoasca fabae*) numbers were greater in the high input level alfalfa plots (Table 3) but so was alfalfa stand density so that leafhopper numbers per stem were probably no greater than in the integrated or low input plots. The same may be said of aphid numbers in alfalfa.

Table 1. Species of lady beetles (COLEOPTERA: Coccinellidae) encountered in 3 crop types during 1994 sampling on ESDSWRF research plots.

	PERCENT COMPOSITION					
	Wheat		Alfalfa		Grass	
	adult	larvae	adult	larvae	adult	larvae
Hippodamia convergens - “convergent”	50	--	14	10	40	--
H. tredecimpunctata tibialis - “13-spotted”	50	--	5	5	20	--
H. parenthesis - “parenthesis”	--	--	57	37	40	--
Coccinella septempunctata - “European sevenspotted”	--	--	17	41	--	--
Coleomegilla maculata - “pink & black”	--	--	7	7	--	--
Cycloneda munda	--	--	tr.[1]	--	--	--
	100%	--	100%	100%	100%	--
(N =	2	--	263	41	10	--)
[# of sampling dates =	1		5		3]	

[1]tr. = <1%

NOTE: Only 2 occurrences of lady beetle pupae, found in alfalfa.

Table 2. Summary of data from sweep net sample collections in ESDSWRF wheat plots, 1994.

TAXON		INPUT LEVEL		
		Low	Integrated	High
Aphids (% of tillers infested)		4.4	0.0	0.0
Wheat Stem Maggot (% of heads damaged)		0.5	1.0	0.8
# of taxa (of 7 taxa groups possible, does not include aphids)		0.5	0.0	0.7
Total numbers - for 7 taxa groups (does not include aphids)		0.7	0.0	0.7
# Damsel bugs	- adult	0.2	0.0	0.2
	- nymph	0.0	0.0	0.0
# Lacewings	- adult	0.0	0.0	0.0
	- larvae	0.0	0.0	0.0
# Lady beetles	- adult (2 species)	0.0	0.0	0.3
	- larvae (none)	0.0	0.0	0.0
Wheat stem maggot	- adult	0.5	0.0	0.2

NOTE: Except for the aphid (% of tillers infested) and wheat stem maggot (% of heads damaged) data, these figures represent the mean value for a subsample consisting of 30 sweeps (two 30-sweep net subsamples per plot). Averaged over the three replicated treatment plots, and both subsamples, for the single sampling date.

Table 3. Summary of data from sweep net sample collections in ESDSWRF alfalfa plots, 1994.

TAXON		INPUT LEVEL		
		Low	Integrated	High
# Aphids		30.4	50.7	57.4
# of taxa (94 8 taxa groups possible, does not include aphids)		4.3	4.5	4.1
Total numbers - for 8 taxa groups (does not include aphids)		31.7	36.5	44.9
# Damsel bugs	- adult	5.1	5.4	7.7
	-nymph	2.3	1.9	3.2
# Potato leafhopper	- adults & nymphs	17.4	21.8	25.3
# Lacewings	- adult	0.2	0.1	0.3
	- larvae	< 0.1	0.2	0.1
# Lady beetles	- adult (6 species)	2.0	2.6	4.1
	- larvae (5 species)	0.2	0.5	0.7
	- pupae	< 0.1	--	< 0.1
# Alfalfa weevil	- adult	4.3	4.1	3.5

NOTE: These figures represent the mean value for a subsample consisting of 30 sweeps (two 30-sweep net subsamples per plot). Averaged over the three replicated treatment plots, both subsamples, and 5 sampling dates.

Table 4. Summary of data from sweep net sample collections in ESDSWRF grass plots, 1994.

Taxon		Cool	Mix	Warm
Aphids (actual numbers)		0.9	0.7	3.1
# of taxa (of 7 taxa groups possible, does not include aphids)		1.7	0.8	0.7
Total numbers - for 7 taxa groups (does not include aphids)		2.6	1.0	0.8
# Damsel bugs	- adult	0.8	0.3	0.3
	- nymph	0.3	0.1	0.1
# Lacewings	- adult	--	--	0.1
	- larvae	0.2	0.1	--
# Lady beetles	- adult (3 species)	0.3	0.2	0.1
	- larvae (none)	--	--	--
Wheat stem maggot	- adult	1.0	0.3	0.2

NOTE: These figures represent the mean value for a subsample consisting of 30 sweeps (two 30-sweep net subsamples per plot). Averaged over the three replicated treatment plots, both subsamples, and 3 sampling dates.

SEEDBANKS AND SEEDLING POPULATIONS OF WEEDS AFFECTED BY MANAGEMENT LEVELS AND CROP ROTATION IN CORN

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Introduction

Crop rotation and tillage management can effect weed management. Crop rotation may change the field weed complex by decreasing certain weed species, causing others to increase, and having no influence on still others. The net effect is due to the different tillage and chemical strategies required for each crop, which in turn influences the development of a particular weed species. Each species also has the ability to compete for water and light. The objective of this study was to determine the impact of alfalfa on weed population dynamics in alfalfa and the following corn crop at three input levels.

Materials and Methods

This study was conducted at the Eastern South Dakota Soil and Water Research Farm at Brookings, SD., The soil type was a Vienna loam (fine loamy mixed; Udic Haploborolls) with a pH of 6.8. Three levels of crop management were imposed on a wheat alfalfa/alfalfa/corn rotation. Corn in the High input system received recommended fertilizer levels for a yield goal of 120 bu/a (about 140 kg of N/ha) and both pre- and post emergence herbicides (Table 1). Corn growth in the moderate input system received about 50% of the recommended fertilizer with a yield goal of about 90 bu/a and preemergence or post emergence herbicide if needed. Low input plots received only mechanical and cultural techniques for weed control and no fertilizer was applied. The three treatments were arranged in a randomized complete block design, and replicated 3 times. Plot size was 40 corn rows 76 cm wide rows and 30 m in length.

Seed collection. Beginning in 1993, soil samples in the corn crop (previous crops wheat-alfalfa(91)/alfalfa(92)/corn(93), were collected prior to weed seedling emergence. The soil samples were taken in 20 locations per input level using a soil core 3.17 cm diameter to a 10 cm depth. These samples were collected in a "W"-shaped pattern in late April frozen until separation of seeds in June. A similar procedure was utilized in 1994 in the corn crop (previous crops wheat-alfalfa(92)/alfalfa(93)/corn(94).

Seed extraction. Soil samples from each location in each plot were extracted separately. Approximately 200-250 g of soil were divided between two Erlenmeyer flasks and an equivalent volume of 0.004 M Sodium metaphosphate dispersant solution was added. The Erlenmeyer flasks were placed on a mechanical shaker (30 excursions/s) for 15 minutes and allowed to sit overnight. Seeds were separated from the soil slurry using a hydropneumatic root elutriator system (Gross and Renner, 1989) (air pressure, 69 kPa; water pressure 448 kPa) with the contents passing through a 508 um sieve. Remaining material was rinsed into a mesh bag (105-mesh polypropylene screening material) and oven-dried at 50°C.

Extracted material was transferred to a petri dish. All entire and cracked seeds were identified and enumerated with the use of a dissecting microscope. A seed manual (Delorit, 1970) was used as a identification reference.

Seedling identification. In the field five permanent quadrants of 0.1 m^2 per plot were placed perpendicular to the corn row. Seedlings were identified, counted by species, and removed in these five quadrants. Dates of sampling for two years were June 10, and August 11, in 1993; and June 2, July 13, and Aug 12 in 1994.

Crop characteristics. Pioneer 3737 corn was planted at rates of 65,000 seeds/ha in May 17, 1993 and in May 10, 1994. Cultivation was conducted in the last week of May and June each year. Corn height and fresh weight per 10 plants were determined, leaf greenness was measured with a chlorophyll meter (SPAD 502), a device that measures the transmittance at two wavelengths within an intact leaf. The meter calculates a numerical value which is proportional to the amount of chlorophyll present in the leaf. Chlorophyll readings were recorded at the most fully expanded leaf at the 10 leaf stage or at anthesis for 20 plants per plot. These 20 leaves were collected, dried and analyzed for total N. Sampling dates were July 28, 1993 and July 26, 1994. Grain yield was recorded at physiological maturity.

Results and Discussion

Weed seed banks. Twelve seed species were identified (nine dicots and three monocots), both entire and cracked seeds were counted and averaged 12,000 seeds per m^2 (Table 2). Due to the difficulty of distinguishing pigweed (Amaranthus spp) from common lambsquarters (Chenopodium album), these seeds were counted together. The total number of weed seeds was similar under the three management input levels. There was a range in the coefficient of variation for each species. Variation in monocot species ranged from 23 to 66%, while variation in dicot numbers ranged from 14% (lambsquarters/pigweed) to 199% (common purslane). Generally, larger seeded dicot weeds had higher coefficients of variation. Dicot species comprised about 80% of the seed bank. Species represented included common lambsquarters/pigweed spp, common ragweed (14%), common purslane (9%), yellow woodsorrel (9%), wild buckwheat (7%), prostrate spurge (4%), prostrate knotweed (3%) and Pennsylvania smartweed (0.2%). The first four small (< 1.5 mm) seed weed species dominated the seed bank. Monocot species represented included green foxtail (11%), yellow foxtail (8%) and barnyardgrass (0-2%).

Individual specie analysis indicated that yellow foxtail density was affected by input level. The lowest number of seeds were observed in the high input plots (421). The integrated (1211) and low (1263) input plots had higher densities. Therefore, of the twelve weed seed species recorded, only yellow foxtail showed a significant difference in contributing to the total weed seed bank and ranged from 4% under high input to 10% in the integrated and low input levels. (Table 1).

Table 1. Insecticide, fertilizer and herbicide applied to two management systems in corn in 1993 and 1994, Brookings, SD.

	Management Level		Date of Application	
Chemical Input	High	Integrated	1993	1994
a) Insecticide (Dyfonate)	Fonofos 3.7 kg a.i/Ha	--	May 10	May 17
b) Fertilizer (N-P-K)	111 kg/ha (13-33-13)	53 kg/ha (13-33-13)	May 10	May 17
c) Nitrogen	122 kg/ha	61 kg/ha	June 11	
	48 kg/ha	--	--	June 21
d) Herbicide preemerged	Alachlor 3.3 kg a.i./ha + Cyanazine 1.0 kg a.i./ha	--	May 20	May 12
e) Herbicide postemerged	Bentazon 0.86 kg a.i./ha + oil concentrate 2.3 l/ha	--	June 15	
		Nicosulfuron 35 g.a.i./ha + oil concentrate + Urea 31 kg N/ha	June 11	
		Cyanazine 0.72 kg a.i./ha		May 23

Table 2. Total number of weed seeds by eleven species under three management input levels, April 19, 1993.

Species	Management Level High	Integrated	Low	F test (P = 0.05)	MSE (X631)	CV (%)
	seeds per m					
a) Total Dicots	9,323	8,850	10,672			
CHEAL	3,884	4,021	3,989	ns	0.8	14
AMBEL	1,516	2,042	1,547	ns	0.8	33
POROL	568	726	2,158	ns	13.2	199
OXAST	1,558	726	1,031	ns	1.4	67
POLCO	895	810	695	ns	0.9	77
EPHHT	600	326	694	ns	0.27	60
POLAV	295	178	526	ns	0.4	112
POLPY	10	21	32	ns	0.004	193
b) Total Monocots	768	2,516	3,662			
SETLU	421 b	1,211 a	1,263 a	*	0.13	23
SETVI	347	1,305	2,336	ns	2.0	66
ECHCG	0	0	63			
Total seeds	10,400	11,500	14,600	ns	38.3	32

[a] Within a row, means followed by the same letter are not significant different at the 0.05 probability level according to a Duncan's Multiple Range Test.

[b] The abbreviations are CHEAL common lambsquarters pigweed complex; AMBEL, common ragweed; POROL, common purslane; OXAST, yellow woodsorrel; POLCO, wild buckwheat; EPHHT, postrate spurge; POLAV, postrate knotweed; POLPY Pennsylvania smartweed; SETLU, yellow foxtail; SETVI, green foxtail; ECHCG, barnyardgrass.

Weeds - 1993

Seedlings 30 days after corn planting. Ten dicot plant species were identified at this time. However, at this stage of development, grass seedlings were not identified to species. Generally, dicot densities were relatively low and none were significantly different among all management input levels. Most of these dicot species had less than ten plants per m^2 (Table 3). Alfalfa shoots represented from 99 to 20% of the total seedlings in the high and low input level plots, respectively, and were the dominant dicot species. Common lambsquarters, redroot pigweed, common ragweed, wild buckwheat, prostrate knotweed, field bindweed, mustard, common cocklebur and common sunflower represented only 10% of total seedlings.

Monocot seedlings represented the 65% of the total seedling population and differences occurred among management input levels. The high input treatment averaged one grass per m^2, but the integrated and low input level had densities of 75 and 125 seedlings per m^2, respectively. The input levels had similar effects in the total number of weed seedlings, i.e. weeds were well controlled in high input, moderated controlled in integrated input, and poorly controlled in low input.

Table 3. Weed seedlings in corn 30 days after planting by plant species under three management input levels, June 10, 1993[a]

Species[b]	Management Level			F test (0.05)	MSE	CV (%)
	High	Integrated	Low			
	seedlings per m^2					
a) Total Dicot	21	45	37	ns	216	42
MEDSA	19	29	23	ns	44	28
CHEAL	0	1	5	ns	13	182
AMARE	0	1	2	ns	5	254
AMBEL	1	9	1	ns	30	144
POLCO	0	1	2	ns	5	254
POLAV	0	3	0	ns	7	300
CONAR	0	0	3	--	--	--
BRSspp	0	0	1	--	--	--
XANST	0	1	0	--	--	--
HELAN	1	0	0	--	--	--
Forbes	1	0	1	--	--	--
b) Total Monocot	1.b	75.ab	125.a	*	1524	58
Total Weeds	21.b	120.a	163.a	*	2135	46

[a] Within a row , means followed by the same letter are not significant different at the 0.05 probability level according to a Duncan's Multiple Range Test.

[b] The abbreviations are MEDSA alfalfa; CHEAL, common lambsquarters; AMARE, redroot pigweed; AMBEL, common ragweed; POLCO, wild buckwheat; POLAV, prostrate knotweed; CONAR, field bindweed; BRSspp, mustard; XANST, common cocklebur; HELAN, common sunflower.

Weeds 90 days after corn planting. Weed counts were carried out in the same quadrants where previous destructive counts were done, therefore, weeds came from late germinated seeds. These late counts reported less species (five dicots and two monocots), and low weed densities (average of 27 per m^2).

Within the dicot species, alfalfa plants were recorded with an average of 6 per m^2. Common lambsquarters, common ragweed, field bindweed, and common cocklebur, had less than five plants each per m^2, in all input levels (Table 4).

Two monocots species were identified, yellow foxtail and green foxtail. Yellow foxtail was more numerous and was affected by management input level. High input had one yellow foxtail per m^2, while the integrated and low input levels had 15 and 24 plants per m^2, respectively, which was about 50% of the entire weed population for each of these input levels.

Table 4. Weeds in corn 90 days after planting by plant species under three management input levels, August 11, 1993[a].

	Species [b]	Management Levels			F test	MSE	CV(*)
		High	Integrated	Low			
		weeds per m^2					
a)	Total Dicot	6	13	11	ns	90	97
	MEDSA	5	9	5	ns	51	111
	CHEAL	1	0	1	--	--	--
	AMBEL	0.b	3.a	2.a	*	0.4	43
	CONAR	0	0	1	--	--	--
	XANST	0	1	1	ns	1	237
	Other	0	1	1	ns	--	--
b)	Total Monocot	1.b	18.a	33.a	*	57	43
	SETLU	1.b	15.ab	24.a	*	65	60
	SETVI	0.b	3.ab	9.a	ns	15	98
Total Weeds		7.b	31.ab	44.a	ns	210	53

[a] Within a row , means followed by the same letter are not significant different at the 0.05 probability level according to a Duncan's Multiple Range Test.

[b] The computed code MEDSA indicates alfalfa; CHEAL, common lambsquarters; AMBEL, common ragweed; CONAR, field bindweed; XANST, common cocklebur; SETLU, yellow foxtail; SETVI, green foxtail.

Weeds - 1994

Weeds 30 days after planting. Weeds in 1994 corn had twelve plant species, eight dicot and four monocots. No specific dicot species dominated the plots. Alfalfa, common lambsquarters, common ragweed, wild buckwheat, field bindweed, common cocklebur, common sunflower, and common milkweed occurred sporadically throughout the three input levels, and densities were less than five plants per m^2 (Table 5), and represented about 5% from total number of seedlings.

Monocot seedlings represented the 95% of the weed population. Four monocot species were identified; yellow foxtail, green foxtail, barnyardgrass and wheat. A group of seedling grasses representing 35% of the entire population were not identified.

Yellow foxtail was the dominant monocot and represented an average of 55% of the total weed population. Furthermore, a significant response to the management input levels was observed with this species. Yellow foxtail under high input levels had low densities (24 seedlings per m^2) in comparison with the integrated and low input levels that had 68 and 118 seedlings per m^2, respectively.

Due to the dominant effect of the monocot species, the total number of weed seedlings, had a significant response to the different management input levels evaluated in this study. High input levels averaged 34 seedlings per m^2, while integrated and low input levels displayed 138 and 207 seedlings per m^2, respectively.

Weeds 60 days after corn planting. The second counting in 1994 was conducted in the same quadrants of previous destructive sampling. At this time dicot weeds occurred only sporadically throughout the plots, and densities per each species were less than five plants per m^2 (Table 6). Six dicot species were observed and included common lambsquarters, common ragweed, wild buckwheat, field bindweed, Pennsylvania smartweed and common purslane. These species represented 10% of the entire weed population and were affected by the management input levels. High and integrated input levels had almost no dicot weeds, while the low input management had 9 plants per m^2.

Monocot weeds represented 90% of the weed population, and three species were observed; yellow foxtail, green foxtail, and barnyardgrass. Yellow foxtail was the predominant weed (60%), followed by green foxtail (30%). Both species were influenced by management input levels. High management input almost eliminated all weeds of both species, while the integrated and low input had 21 and 39 yellow foxtail per m^2, respectively. Control of green foxtail in the high and integrated input level was effective, while the low input had 23 weeds per m^2.

Total number of weed was significantly affected by the management input levels. High and integrated input levels had few weeds, 4 and 24 per m^2, respectively, while the low input level had a total of 77 weeds per m^2.

Table 5. Weed seedlings in corn 30 days after planting by plant species under three management input levels, June 2, 1994[a].

Species [b]	High	Integrated	Low	F test	MSE	CV(*)
	Management Levels					
	seedlings per m^2					
a) Total Dicot	5	2	11	ns	38	107
MEDSA	2	1	0	ns	5.2	254
CHEAL	1	1	2	ns	1.6	120
AMBEL	0	0	1	ns	1.6	300
POLCO	1	0	1	ns	0.7	122
CONAR	0	0	1	ns	1.6	300
XANST	0	1	4	ns	7.2	171
HELAN	0	0	1	ns	0.4	300
ASCSY	1	0	0	ns	1.6	300
b) Total Monocot	29.b	136.ab	196.a	ns	4884	58
SETLU	24.b	68.b	118.a	ns	1624	57
SETVI	1	3	13	ns	140	214
ECHCG	0	1	0	ns	0.4	300
Grass	4	63	65	ns	7116	191
Wheat	1	0	0	ns	0.4	300
Total	34.b	138.ab	207.a	**	5378	58

[a] Within a row , means followed by the same letter are not significant different at the 0.05 probability level according to a Duncan's Multiple Range Test.

[b] The abbreviations are MEDSA alfalfa; CHEAL, common lambsquarters; AMBEL, common ragweed; POLCO, wild buckwheat; CONAR, field bindweed; XANST, common cocklebur; HELAN, common sunflower; ASCSY, common milkweed; SETLU, yellow foxtail; SETVI, green foxtail; and ECHCG, barnyardgrass.

Table 6. Weeds in corn 60 days after planting by plant species under three management input levels, July 13, 1994[a].

Species [b]	Management Level High	Integrated	Low	F test (0.05)	MSE	CV (%)
	weeds per m^2					
a) Total Dicots	2.ab	0.b	9.a	*	9.2	84
CHEAL	1	0	5	ns	7.2	150
AMBEL	1	0	1	ns	1.2	173
POLCO	1	0				
CONAR	0	0	1	ns	1.6	300
POLPY	0	0	1	ns	1.6	300
POROL	1	0	0	ns	0.4	300
b) Total Monocot	2.b	24.b	69.a	**	142	38
SETLU	2.b	21.ab	39.a	*	75	41
SETVI	0.b	3.b	28.a	ns	46	66
ECHCG	0	0	1	--	--	--
Total Weeds	4.b	24.b	77.a	**	178	38

[a] Within a row, means followed by the same letter are not significant different at the 0.05 probability level according to a Duncan's Multiple Range Test.

[b] The abbreviations are CHEAL, common lambsquarters; AMBEL, common ragweed; POLCO, wild buckwheat; CONAR, field bindweed; POLPY, Pennsylvania smartweed; POROL, common purslane; SETLU, yellow fox

Corn Plants Characteristics

1993. Corn plants were affected by input levels. Chlorophyll content was significantly different for each input level (Table 7). Chlorophyll relative values with respect to the high input were lower, with the integrated and low input having relative values of 94% and 79%, respectively. Nitrogen content in these leaves showed a similar pattern. N content high and integrated input levels were not different, with an average value of 3.1% of nitrogen content as observed in these treatments, however, a significant reduction occurred at low input levels where the leaves had 2.4% of nitrogen content (Table 7).

Height, total fresh weight, and grain yield of corn were significant different between treatments that received herbicide and fertilizer (high and integrated) versus the treatment without these inputs (low). Height in high and integrated inputs were about 130 cm and in the low input was 90 cm. Total fresh weight in high and integrated inputs were about 255 g per plant and in the low input was 120 g per plant, before anthesis. Grain yield at high and integrated input levels was in average 5.9 ton/ha and in the low input was 5.0 ton/ha.

Table 7. Chlorophyll, leaf tissue nitrogen content (N), height, total fresh weight (TFW) under three management input levels, July 28, 1993 and grain yield at harvest.

Input	Chlorophyll	N (*)	Height (cm)	TFW (g/pl)	Yield (ton/ha)
High	51 a (1.00)	3.17 a	134 a	288 a	6.2 a
Integrated	48 b (0.94)	2.96 a	125 a	240 ab	5.5 ab
Low	41 c (0.79)	2.43 b	92 g	122 b	5.0 b
F test	**	**	*	ns	
MSE	1.2	0.01	155	3702	
CV (%)	2.3	3.7	11	28	

1994. Values of chlorophyll, height and total fresh weight per plant evaluated in the summer of 1994, showed significant (P=0.05) and similar effects to the previous year. High and integrated treatments had high chlorophyll content (values above 55), plant height (230 cm), and fresh weight (680 g/plant) at anthesis. Low input data were significantly different from these two treatments with chlorophyll content about 53, height about 210 and fresh weight of 540 g/plant.

Weather conditions during 1994 for corn were better because of warmer temperature at the beginning of the season in comparison with 1993, which resulted in better conditions for the growth of the corn and weeds. Total competition in the high input was about 38 weeds per m^2, in the integrated about 162 and in the low input about 284 weeds per m^2, which are very similar to previous year.

Table 8a. Chlorophyll, height, and total fresh weight (TFW) under three management input levels, July 26, 1994.

Input	Chlorophyll	Height (cm)	TFW (g/pl)
High	59 a (1.00)	232 a	705 a
Integrated	55 ab (0.94)	226 a	662 a
Low	53 b (0.90)	207 b	540 b
F test	*	**	**
MSE	2.9	16	910
CV (%)	3	2	5

Implication for weed control

Weeds seed banks and weed population shifts associated with changing agronomic practices are complex and dynamic processes which are not easy to predict. Management input levels did not alter significantly the weed seed banks under this particular rotation of corn after two years of alfalfa. Predictions that an integrated and low management input levels would led to an incremental increase in monocot seeds and weeds were realized in this study.

Yellow and green foxtail were the dominant monocots that shifted under integrated and low inputs and information about the threshold values at which these weeds populations will cause a deleterious effect is needed.

Integrated input levels had levels of soil fertility and weed populations that were not detrimental to several plant characteristics and grain yield.

MANAGEMENT OF CORN ROOTWORM ADULTS USING SEMIOCHEMICAL INSECTICIDE-BAIT APPLIED WITH A HIGH CLEARANCE SPRAYER

Laurence D. Chandler
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Over the last five years the Northern Grain Insects Research Laboratory has been the leader in the development of a new insecticide bait for use against corn rootworm beetles. The bait is composed of cucurbitacin (a compound which acts as a beetle feeding stimulant), a toxicant (carbaryl), and various carriers. To date the bait has been effective against both northern and western corn rootworm adults and is being sold commercially under the names Slam (Microflo Co./BASF Inc.) and Compel (Ecogen Inc.). For the bait to work properly it must be applied efficiently. In many instances poor aerial application methods have resulted in bait failure. Without concise, accurate application protocols widespread adoption of bait use will be slow to occur. Use of high clearance sprayers to apply insecticide baits provides feasible alternatives to aircraft in environmentally sensitive areas or irregular shaped fields that are difficult for planes to treat. The purpose, therefore, of this study was to evaluate ground application methods that are likely to be used in bait application and to identify methods of application to enhance bait efficacy.

Methods and Materials

Field corn was planted on 5 May 1994 in a 4 hectare field at the Eastern South Dakota Soil and Water Research Farm in Brookings County, SD. The field was divided into 24 plots each 26 rows (76 cm) wide and 60 meters long. Ten meter buffers were established between plots. Five sprayer application treatments and an untreated control were then arranged in a randomized block design with four replications. Treatments were as follows:

1. Untreated control;
2. Slam - 19 L/ha; 1 nozzle/row over canopy;
3. Slam - 37 L/ha; 1 nozzle/row over canopy;
4. Slam - 19 L/ha; 2 nozzles on single drop; every other row;
5. Slam - 37 L/ha; 2 nozzles on single drop; every other row;
6. Slam - 37 L/ha; 2 nozzles on single drop; every row;

Slam was applied twice during silking at the rate of 561 gms/ha of product in the above listed water volumes. Applications were made with a Modern Flow high clearance sprayer equipped with a 12 row boom and TX-4 hollow cone nozzles. Applications were made at 0.9 kg/cm^2 and at variable speeds to accommodate the differing spray volumes. Drops extended 91 cm into the plant canopy and nozzles were pointed upward at 45° angles. The effectiveness of the applications was determined using corn rootworm beetle counts from 25 plants/plot, number of dead beetles in 11 X 15 cm metal trays placed on the ground (3/plot), and counts of the number of beetles on yellow sticky traps. Lady beetles in metal trays and on plants were also noted. Observations of the above factors were made before insecticide bait application and periodically afterwards. Means and standard errors were calculated for all data. Analysis of variance was conducted for data from each observation date and means separated using Fishers LSD.

Results

The number of northern and western corn rootworm beetles per plant and on yellow sticky traps was significantly ($P \leq 0.05$) reduced following each of two applications of Slam in all tested treatments. The average number of western corn rootworm adults ranged from 0.02 to 0.05/plant in treated plots compared to 0.14/plant in the untreated controls 3 days after the second application. Average number of northern corn rootworm adults ranged from 0.16 to 0.37/plant in the treated plots compared to 0.53/plant in the untreated control plots 3 days after the second application. Similar trends were observed on yellow sticky traps. Although these numbers are low one must remember that first year corn should not have large populations of rootworms during the growing season. The number of dead northern corn rootworm beetles in metal trays was numerically greater in all high clearance sprayer plots than in the untreated control plots following the initial Slam application. Total number of dead northern beetles collected during the entire evaluation period, however, was similar ($P > 0.05$) in the untreated control and the treatment using 19L/ha of water applied using drops on every other row. Total number of dead western corn rootworm adults was greater ($P \leq 0.05$) in all treatments using 37L/ha of total spray volume compared to the untreated plots. Dead lady beetles in metal trays and lady beetle counts/plant were similar ($P > 0.05$) in number in all high clearance sprayer treatments throughout the duration of the study. No dead lady beetles were observed in untreated plots.

Conclusion

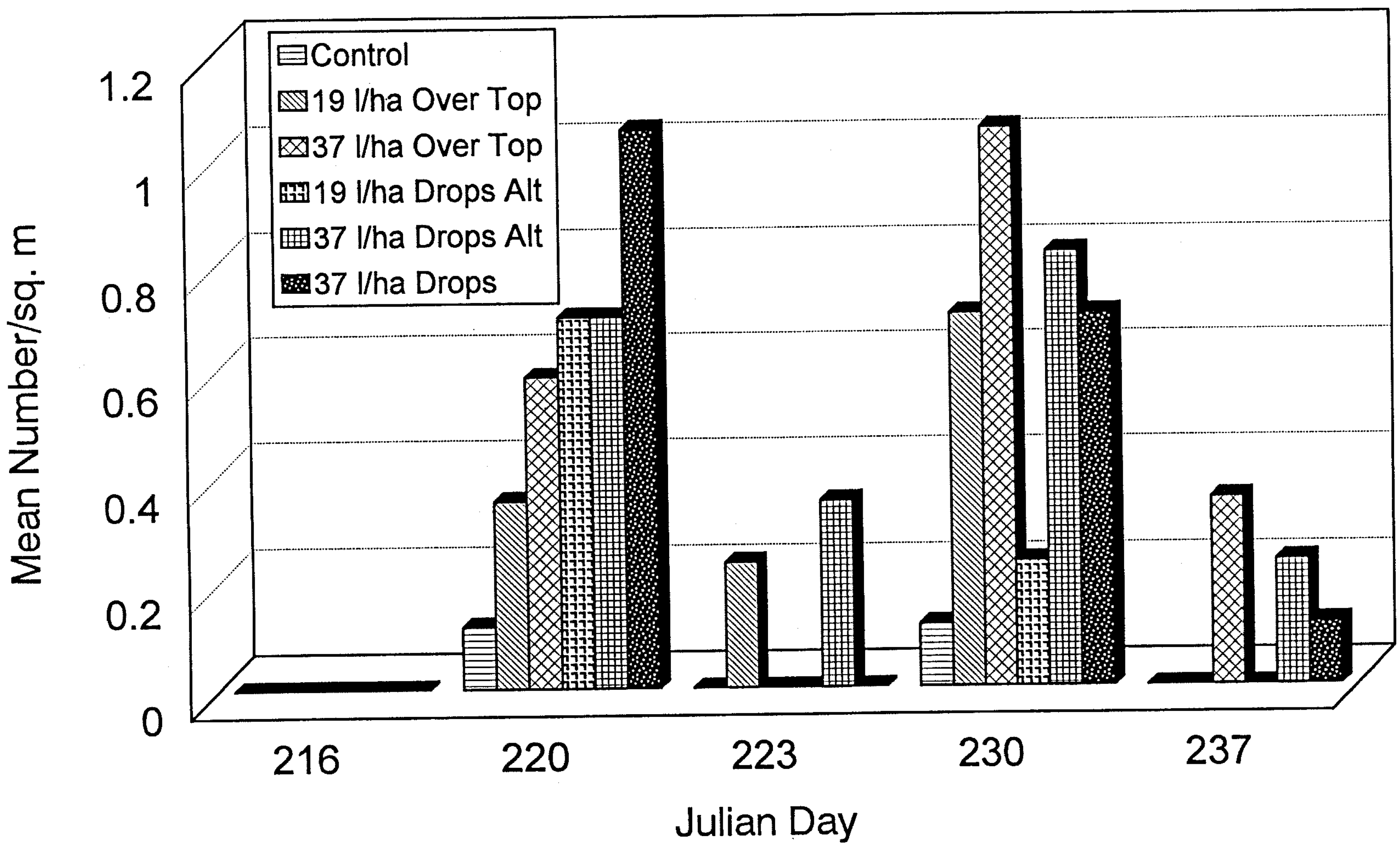
The high clearance sprayer methods for applying insecticide baits tested in this study were effective in reducing total numbers of northern and western corn rootworm adults. However, the percent reduction of northern corn rootworm adults was not as great as the reduction of western corn rootworm adults using the tested application methods. Use of high clearance sprayers appears to be a feasible alternative to aerial application. Although all high clearance sprayer methods significantly reduced adult rootworm numbers, it appeared that use of higher water volumes to carry the insecticide-bait may be of importance. High volume (37L/ha) applications worked especially well with the low density western corn rootworm population. Reduction in lady beetle numbers immediately following Slam applications is important. Although the lady beetle numbers recovered fairly quickly, this initial reduction should be considered when developing corn management practices based on the insecticide bait. No one application method was found to be less harmful to lady beetle populations. Further studies will be conducted to refine application methods and to determine the impact of insecticide baits on non-target insects.

Acknowledgment

Special thanks are extended to Gerry Sutter for his assistance and contributions to this study. Denise Hovland, Deb Hartman, Lynn Fleming, Kurt Dagel, and Bart Larson are acknowledged for their assistance with the study. Micro-Flo Co. in cooperation with BASF Corp. provided the insecticide-bait product.

1994 Soil and Water Farm

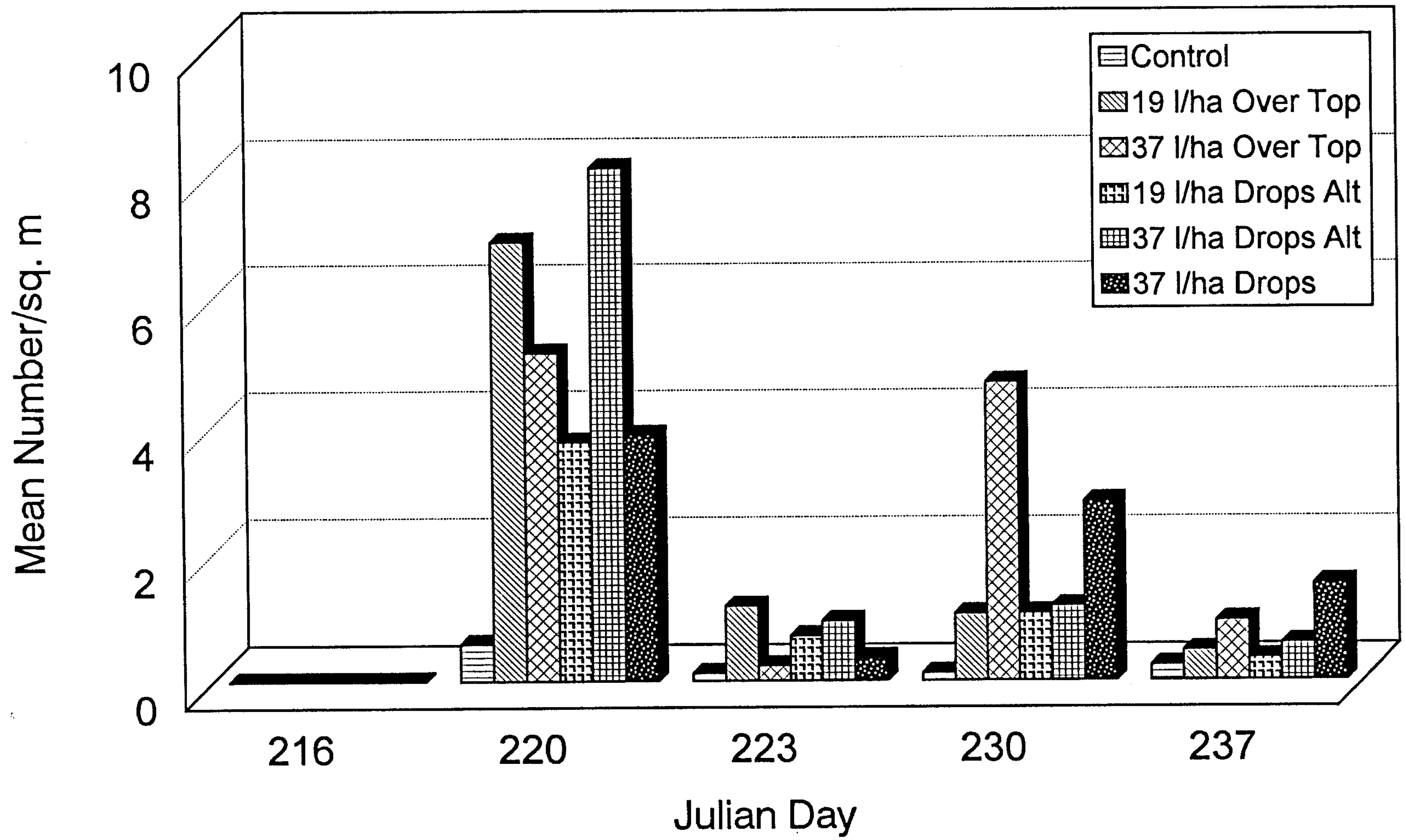
Westerns - Dead Beetle Trays



Sprayed on 217 and 227

1994 Soil and Water Farm

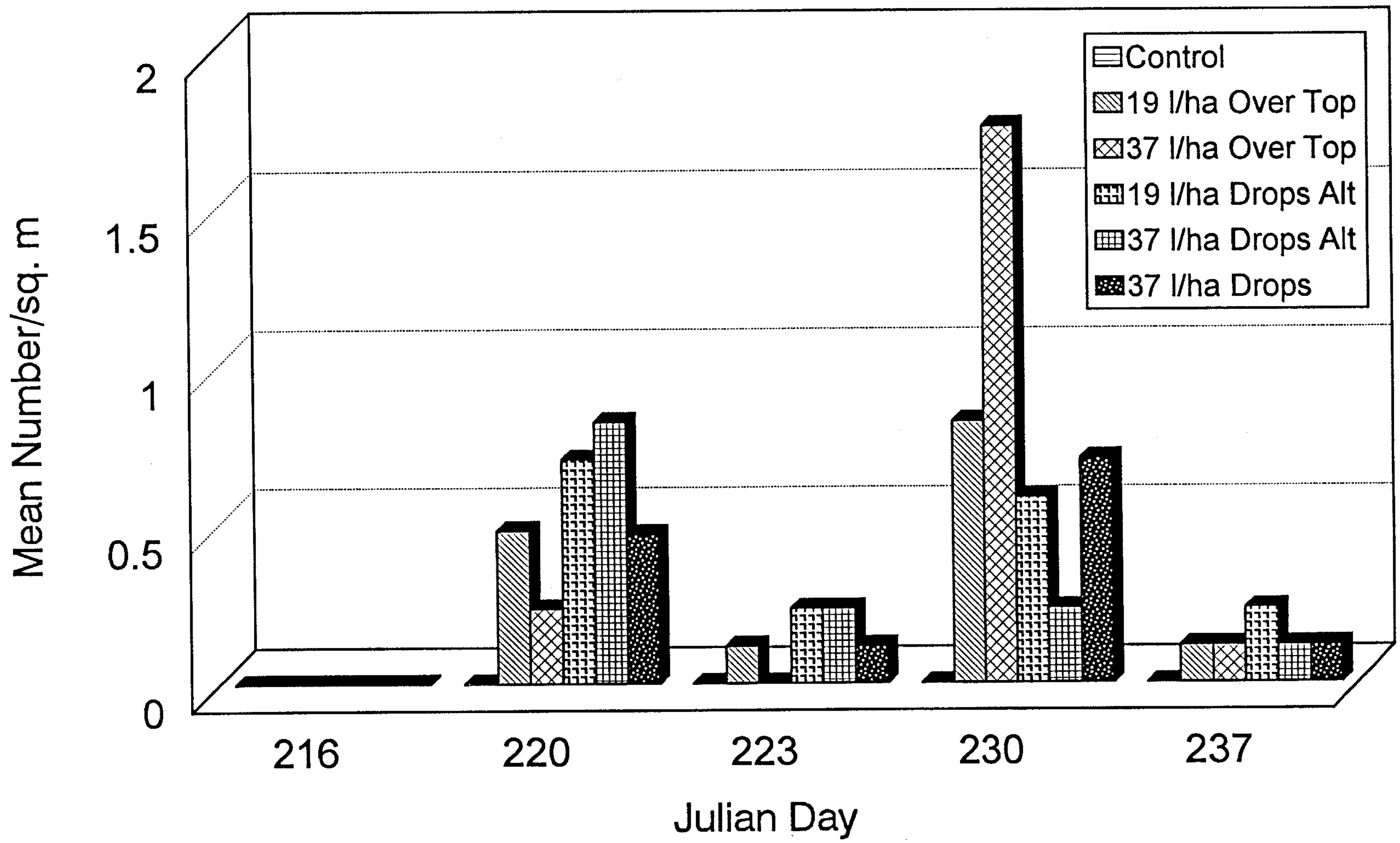
Northerns - Dead Beetle Trays



Sprayed on 217 and 227

1994 Soil and Water Farm

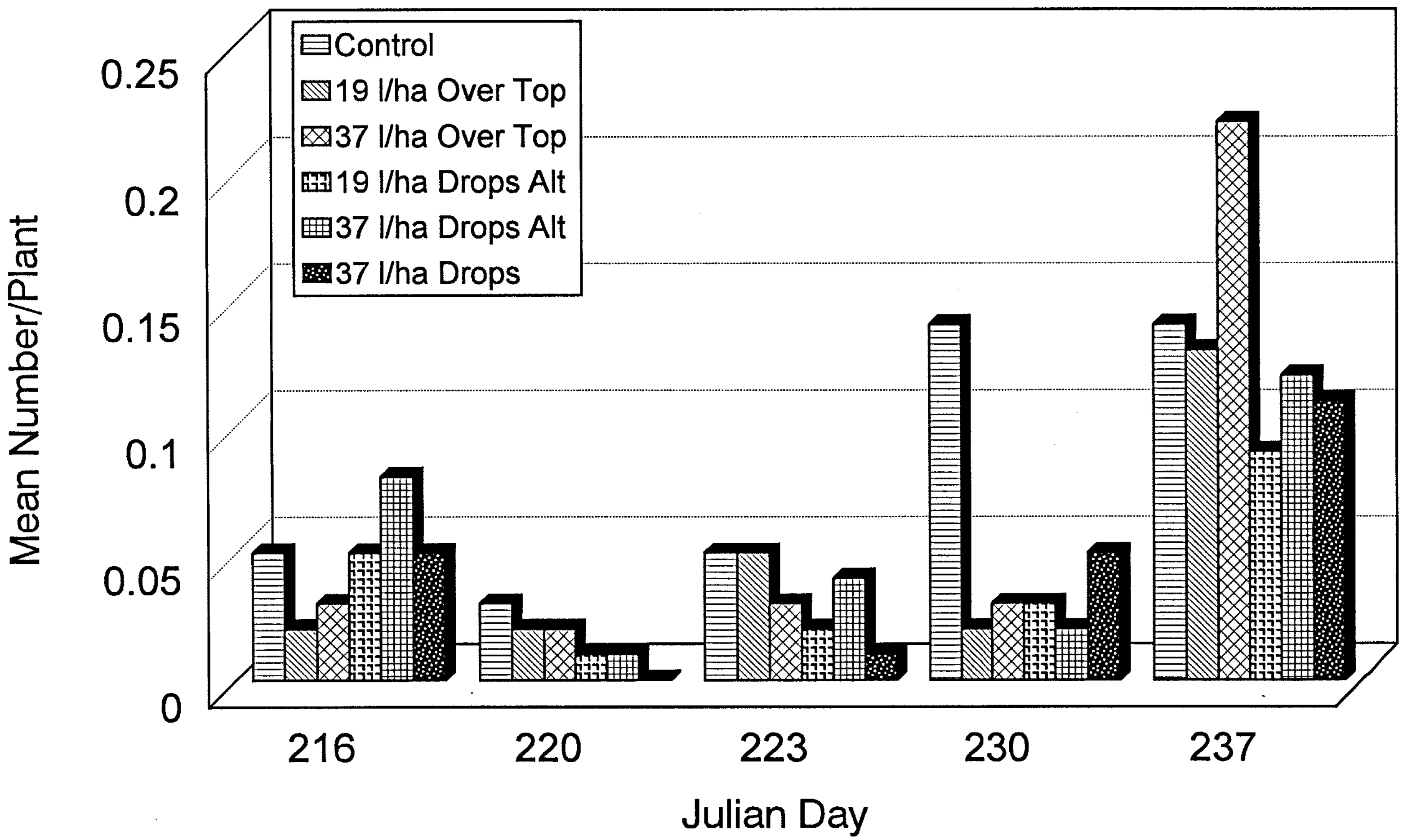
Lady Beetles - Dead Beetle Trays



Sprayed on 217 and 227

1994 Soil and Water Farm

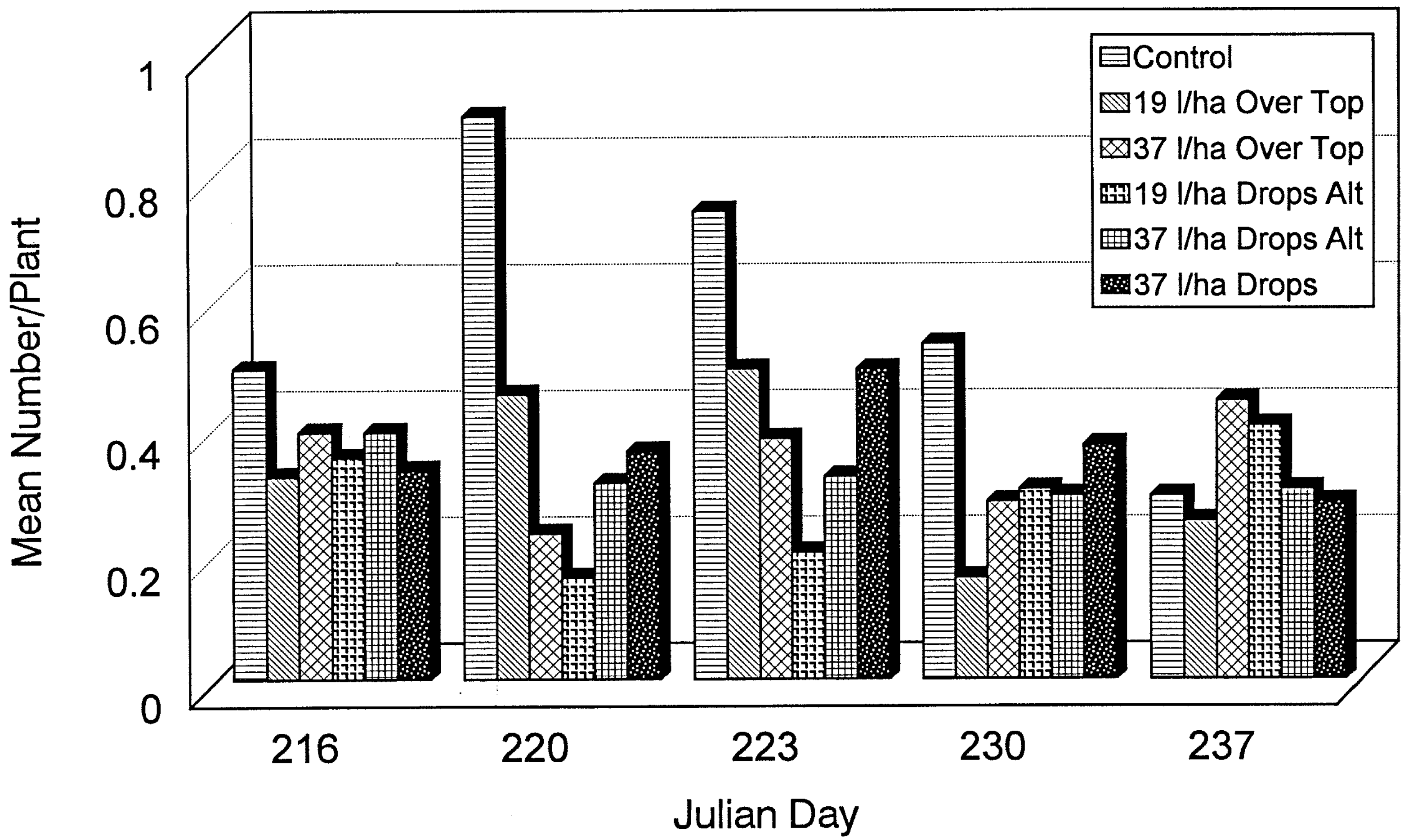
Westerns - Plant Counts



Sprayed on 217 and 227

1994 Soil and Water Farm

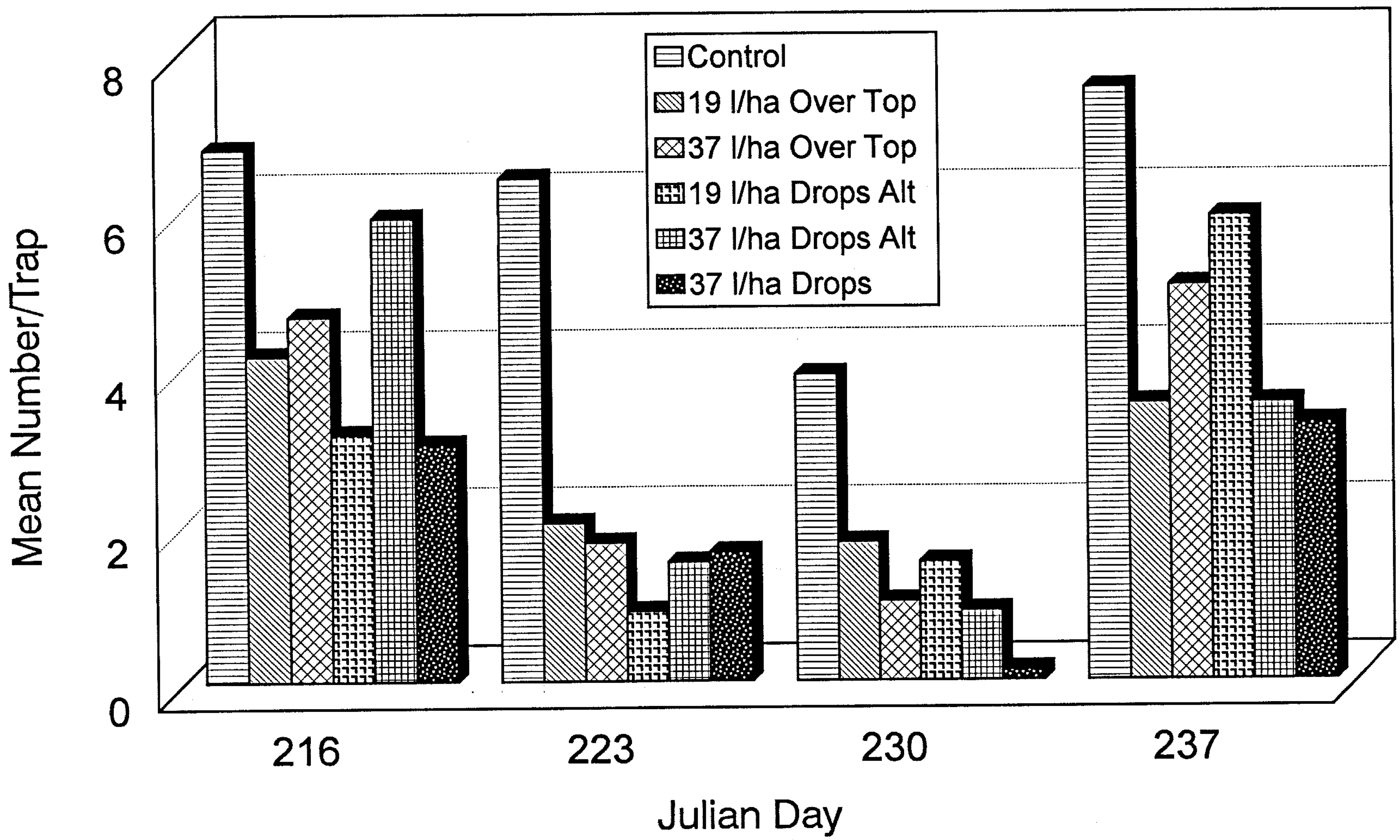
Northerns - Plant Counts



Sprayed on 217 and 227

1994 Soil and Water Farm

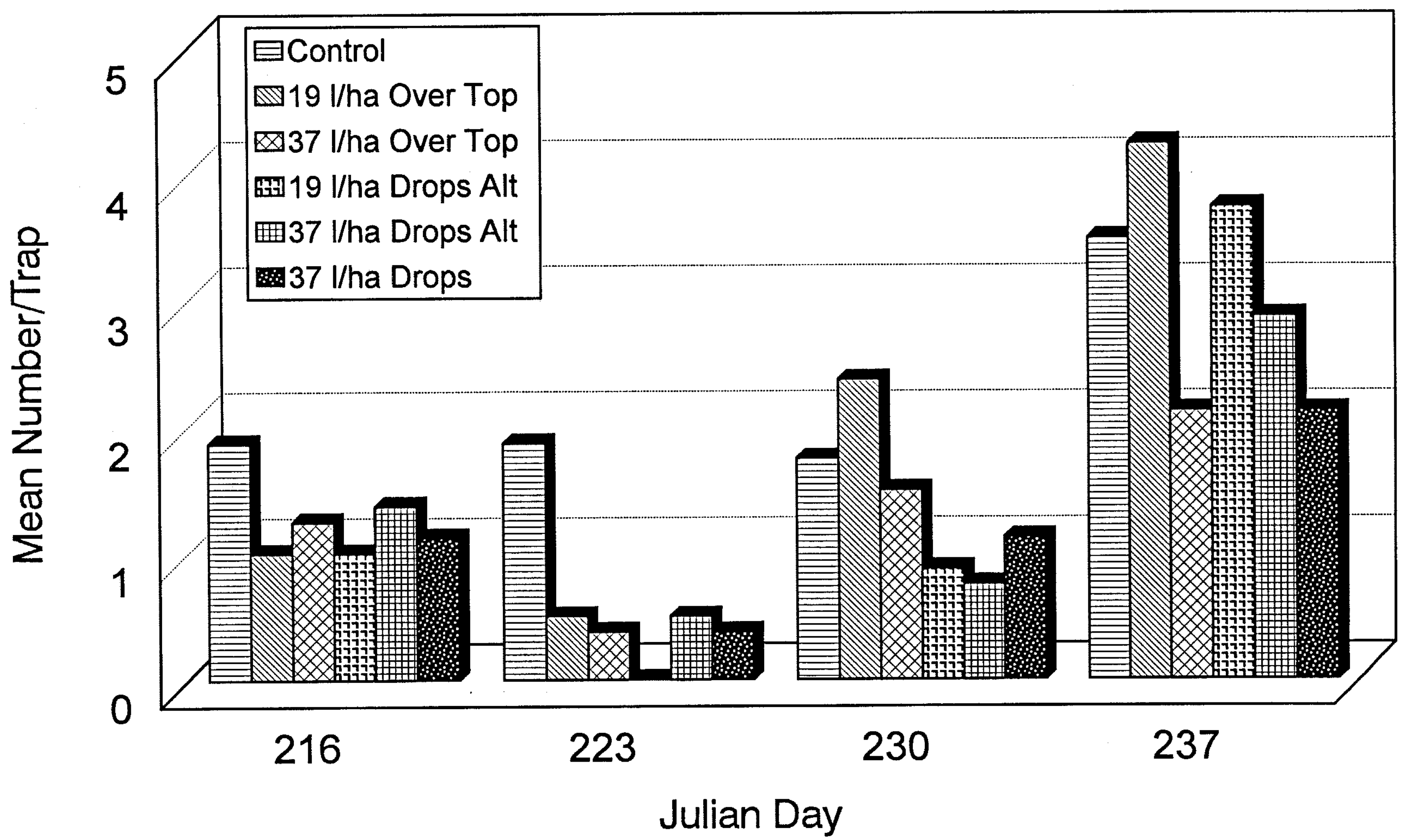
Northerns - Pherocon AM Traps



Sprayed on 217 and 227

1994 Soil and Water Farm

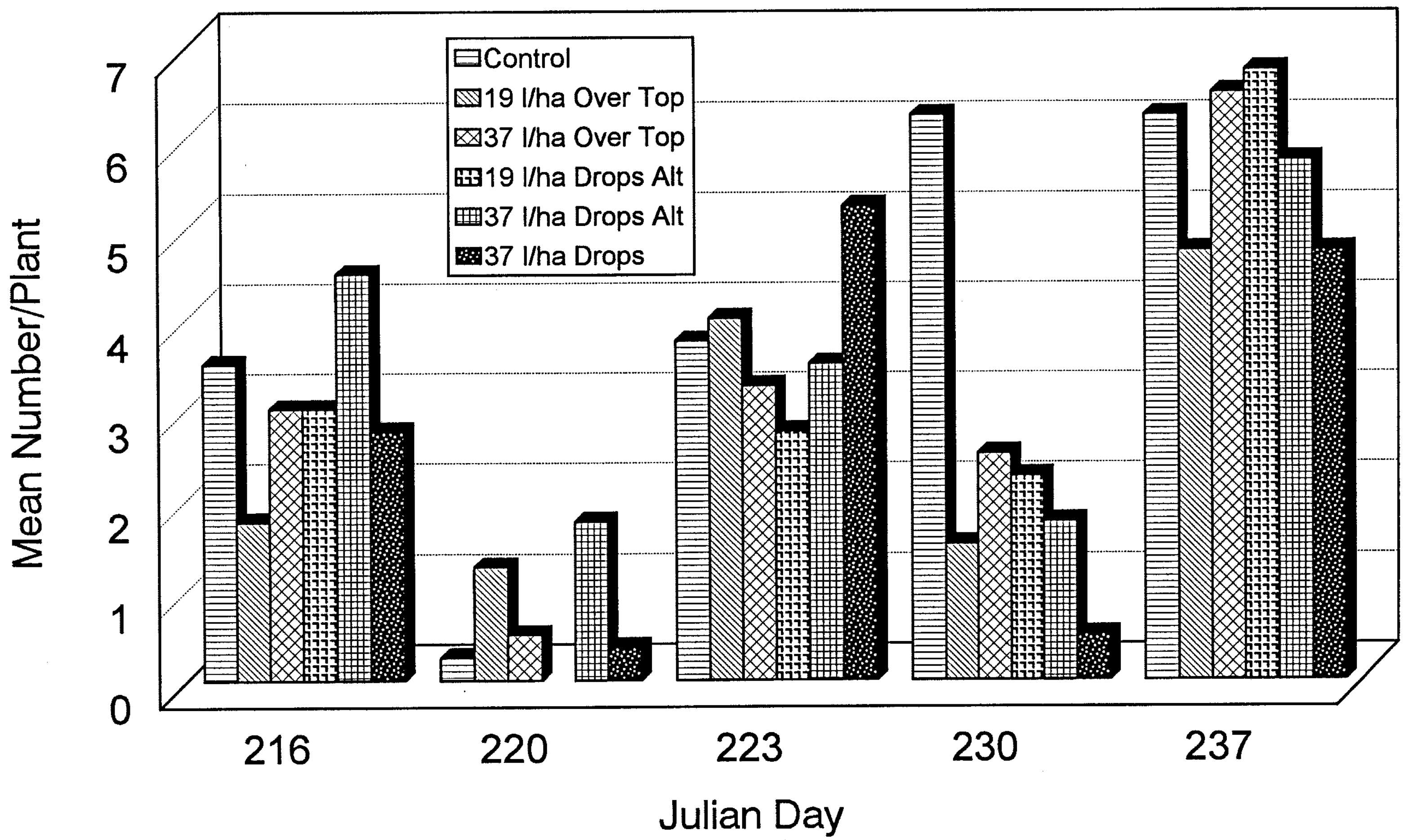
Westerns - Pherocon AM Traps



Sprayed on 217 and 227

1994 Soil and Water Farm

Lady Beetles - Plant Counts



Sprayed on 217 and 227

1994 ROOTWORM EMERGENCE IN CONTINUOUS CORN WITH AND WITHOUT INSECTICIDE

W. David Woodson
USDA, ARS Northern Grain Insects Research Laboratory

There are a wide variety of management schemes utilized in maize production. Tillage may be conventional, ridge till or no till; crop rotation may be a simple corn soybean rotation, a four crop rotation or none at all; pesticide use can be quite high or nonexistent. The purpose of this study is to examine how some of these different practices affect rootworm populations dynamics and maize yield. Plot areas were established that had either low, integrated or conventional inputs. Low input plots had neither herbicides nor insecticides applied and are disked. Integrated plots had herbicides applied but no insecticides applied and are chisel plowed. Conventional plots were treated with both herbicides and insecticides and are moldboard plowed.

Plots were sampled in the spring prior to planting to estimate the egg density of each rootworm specie. Four soil samples per plot were taken, the eggs washed from the soil and the eggs were identified. During the growing season four soil samples per plot were taken weekly to determine larval development. Samples were taken to the lab, placed in Berlaise funnels for 48 hours and the larvae collected. During the first week of July four emergence traps were placed per plot and adults counted twice per week.

The high input continuous corn plots had large numbers of rootworms emerging for about six weeks (Figs. 1 and 2). These plots received both herbicide and insecticide treatments prophylactically. The northern corn rootworm has become the dominant rootworm species in these plots, probably due to the use of soil insecticides . In the high input plots we found twice as many western corn rootworm eggs as those of the northern corn rootworm when we sampled in early May 1994. Based on this information you might expect the western to dominate these plots. However, Piedrahita et al. (1985) found that in mixed populations the western corn rootworm larvae will aggregate close to the base of the plant. This situation allowed the insecticide that was placed in a six inch band at planting to have a greater impact on the western corn rootworm larvae than the northern corn rootworm larvae. The northern corn rootworm larvae in mixed populations tend to be dispersed farther from the base of the plant in mixed populations (Piedrahita et al. 1985) and escape the insecticide treatment. Therefore, with western larval numbers severely reduced the northern was able to dominate the population dynamics of the field with over two and half times more northern adults emerging from the high input fields than western adults.

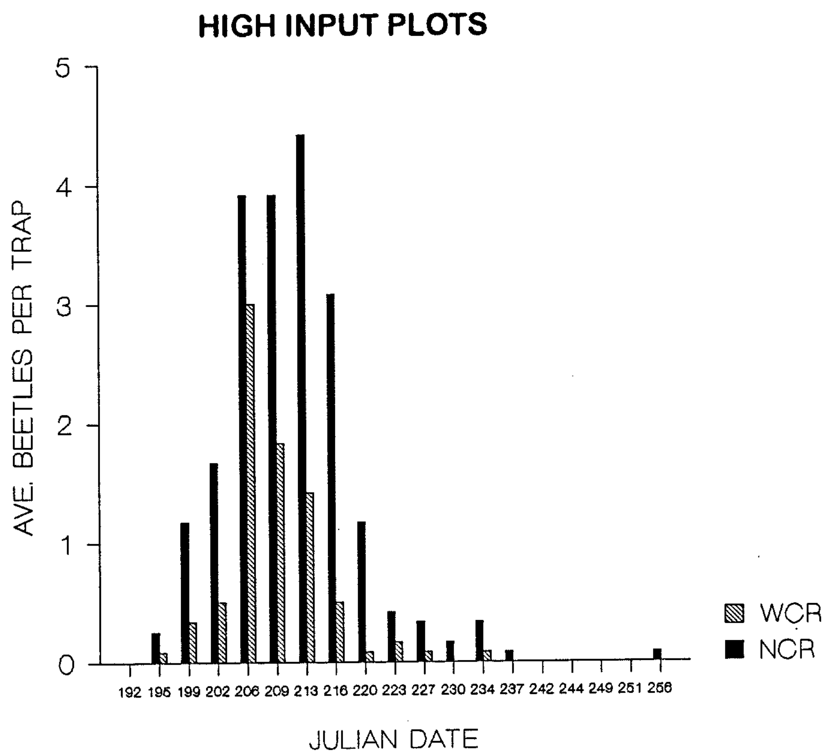
The integrated input continuous corn plots had large numbers of northern corn rootworms this past year but very few western corn rootworms (Fig 3). These plots received no insecticide treatment but did receive limited herbicide treatments. The spring egg counts (Fig. 2) show that there were approximately seven times more northern corn rootworm eggs than western corn rootworm eggs in these plots at planting. In this case the usually more competitive western corn rootworm (Woodson, 1994) was apparently overwhelmed by the numerically superior northern corn rootworm. This situation resulted in almost twenty times more northern corn rootworms emerging than westerns from these plots.

The low input continuous plots had quite low numbers of western and northern corn rootworm emerging this year (Fig. 4). These plots received no herbicide or insecticide treatment, cultivation was used for weed control. The spring eggs counts (Fig. 2) indicated little difference between these plots and the integrated input plots in terms of western and northern eggs. Larval counts made through out the season found very few larvae in these plots. This was most likely due to the large number of weeds in these plots which prevented larvae from establishing.

References

Piedrahita, O., C. R. Ellis, and J. P. Bogart. 1985. Interaction of northern and western corn rootworm larvae (Coleoptera: Chrysomelidae) in a controlled environment. Environ. Entomol. 14(2): 138-141.

Woodson, W. D. 1994. Interspecific and intraspecific competition between Diabrotica virgifera virgifera and Diabrotica barberi (Coleoptera: Chrysomelidae). Environ. Entomol. 23: 612-616.


HIGH INPUT PLOTS
AVE. BEETLES PER TRAP
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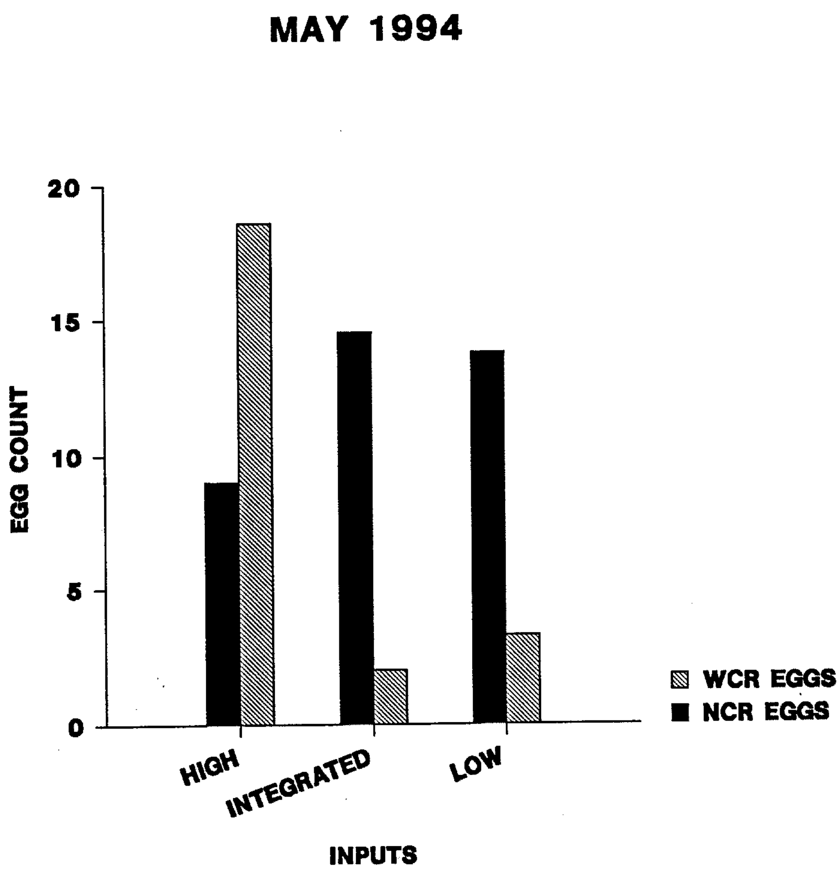
MAY 1994
20
15
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5
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EGG COUNT
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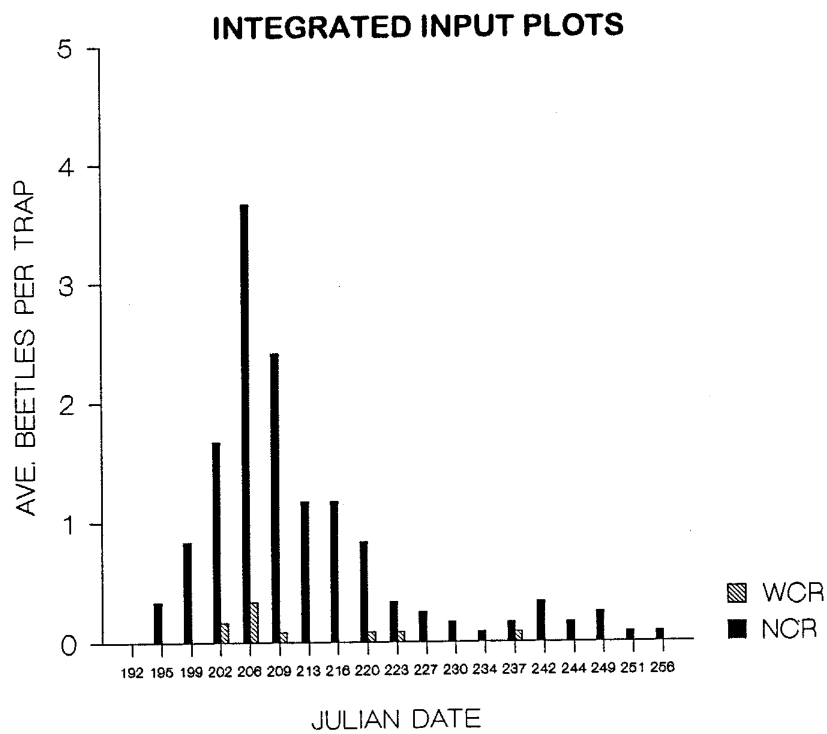
INTEGRATED INPUT PLOTS
AVE. BEETLES PER TRAP
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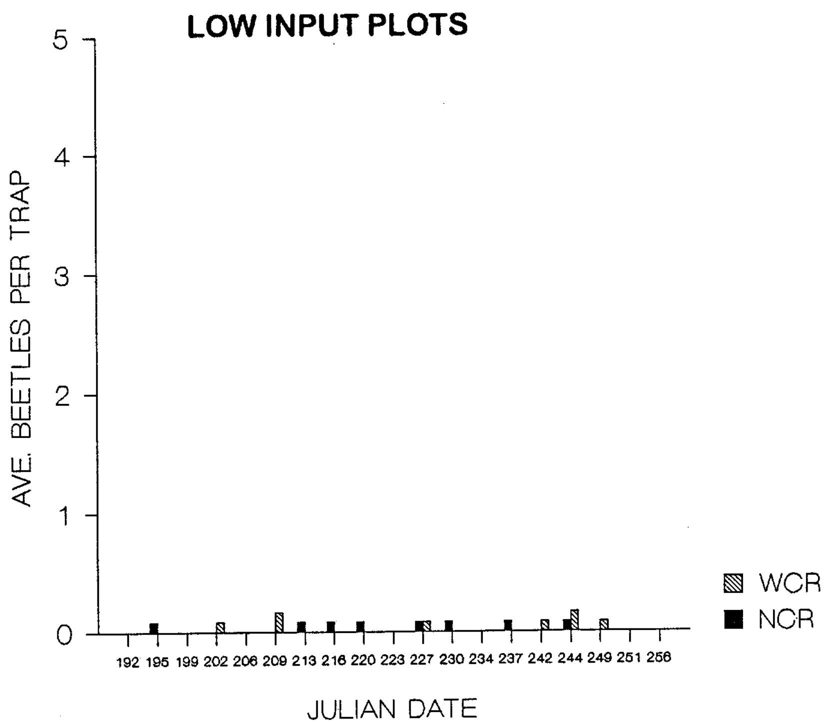
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JULIAN DATE
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MONITORING POPULATIONS OF GROUND BEETLES (CARABIDAE) IN TILLAGE/ROTATION PLOTS

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USDA, ARS Northern Grain Insects Research Laboratory

Ground beetles (Coleoptera: Carabidae) occur abundantly in many field crop plantings. They are generally regarded as beneficial insects, but their impact as predators of pest insects and consumers of weed seeds is not well understood. We have monitored populations of ground beetles during the growing seasons over three years by means of pitfall traps. Objectives of this ongoing study have been to determine whether ground beetles may be associated with particular crops, rotational sequences, or level of farming input. The eventual goal of the project is to gain enough understanding of the ecology of ground beetles so that their beneficial impact may be enhanced through management of cropping systems.

Materials and Methods

One pitfall trap was placed in the approximate center of each plot. To prevent permanent impact on population density of ground beetles, traps were active for only 48 hr at weekly intervals. When not active, the traps were covered with plastic Petri plates to prevent undue impact on carabid populations in the plot area and to keep rainfall and soil out of the containers. Collections commenced the week of 18 May 1995 and continued through the week of 6 September 1995.

Results and Discussion

There were 33 carabid species collected during the season (Table 1). Four species, *Cyclotrachelus sodalis*, *Pterostichus lucublandus*, *Harpalus pensylvanicus*, and *Bembidion quadrimaculatum*, comprised about 80% of the total of 3365 individuals collected (Table 1). There were significant differences in total numbers of species collected when rotational systems were compared . This difference is reflected in Figure 1a, where a four-year corn / soybean / grain / legume (CSGL) rotation shows greater abundance and diversity (number of species) than the other rotations. Carabids also were generally more abundant in corn and soybean plantings (Figure 1b) than in alfalfa or wheat.

There were apparent differences in early season diversity (# species collected) across input levels over all crops in the study (Figure 1c). Low input plots had early season activity (May and June) of more carabid species than did the integrated or high input plots. In collections from all corn plots, only numbers of *H. pensylvanicus* varied significantly with farming input, among the four species most frequently collected. Occurrence of this species was greater in low input plots than in the higher input plots.

Dominance of the four most frequently collected species is shown in Figure 2 for the various treatments of input level, crop type, and rotational system. In low input plots, *H. pensylvanicus* was the dominant species (Figure 2a). In the integrated plots, *C. sodalis* was the dominant species, while there was no apparent dominance of any of the three most abundant species in the high input plots (Figure 2a). A predaceous species *C. sodalis* was dominant in all crops except wheat (Figure 2b), in which *P. lucublandus* was most prevalent. For all rotational systems, *C. sodalis* was consistently the most dominant species (Figure 2c).

In soybean plots, total collections of all beetle species were significantly higher in low and integrated input systems than in the high input systems. There were no rotation effects on any of the four most frequently encountered species in soybean. Since *H. pensylvanicus* is known to feed on weed seeds, its abundance in the low input plots may be explained in terms of habitat preference for the weedier environment in those plots. Other crops, i.e. grain or alfalfa, had no statistically significant effect on numbers of carabids collected.

The data suggest an association of *H. pensyvanicus*, a seed feeder, with the low and integrated input plots. A possible explanation for this is the presence of more weeds in those plots, providing a food resource for that species. The impact of *H. pensyvanicus* on weed seed populations in is unknown. Reasons for the dominance of *C. sodalis* in the integrated plots when compared to high input plots is not known, although a possible explanation may be sensitivity to chemicals used in the high input plots.

Table 1. Ground beetles collected in pitfall traps from tillage/rotation/input plots on the Eastern South Dakota Soil and Water Research Farm during 1994.

Species	Total Collected	Percent of Total	Cumulative Percent
Cyclotrachelus sodalis	1344	39.9	39.9
Pterostichus lucublandus	737	21.9	61.8
Harpalus pensylvanicus	381	11.3	73.1
Bembidion quadrimaculatum	239	7.1	80.2
Abacidus permundus	138	4.0	84.2
Agonum placidum	87	2.6	86.8
Chlaenius laticollis	78	2.3	89.1
Harpalus erythropus	75	2.2	91.3
Bembidion rapidum	60	1.8	93.1
Harpalus caliginosus	33	1.0	94.1
Brachinus cordalis	32	0.9	95.0
Amara carinata	21	0.6	95.6
Agonum cupripenne	21	0.6	96.2
Anisodactylus rusticus	16	0.5	96.7
Amara obesus	16	0.5	97.2
Pterostichus chalcites	14	0.4	97.6
Tachys incurvus	13	0.4	98.0
Chlaenius sericeus	10	0.3	98.3
Scarites substriatus	8	0.2	98.5
Tachys inornatus	8	0.2	98.7
Agonoderus leconti	6	0.2	98.9
Notiophilus semistriatus	5	0.1	99.0
Pterostichus femoralis	5	0.1	99.1
Scarites subterraneus	4	0.1	99.2
Calosoma calidum	4	0.1	99.3
Harpalus erraticus	2	*	
Chlaenius pensylvanicus	2	*	
Harpalus bicolor	1	*	
Bembidion rupicola	1	*	
Loricera pilicornis	1	*	
Agonum gratiosum	1	*	
Clivina impressifrons	1	*	
Pterostichus melanarius	1	*	

* Values less than 0.1 % not included.

Fig. 1a. Cumulative # Species Versus Total # Ground Beetles Collected from Four Rotational Cropping Systems in 1994

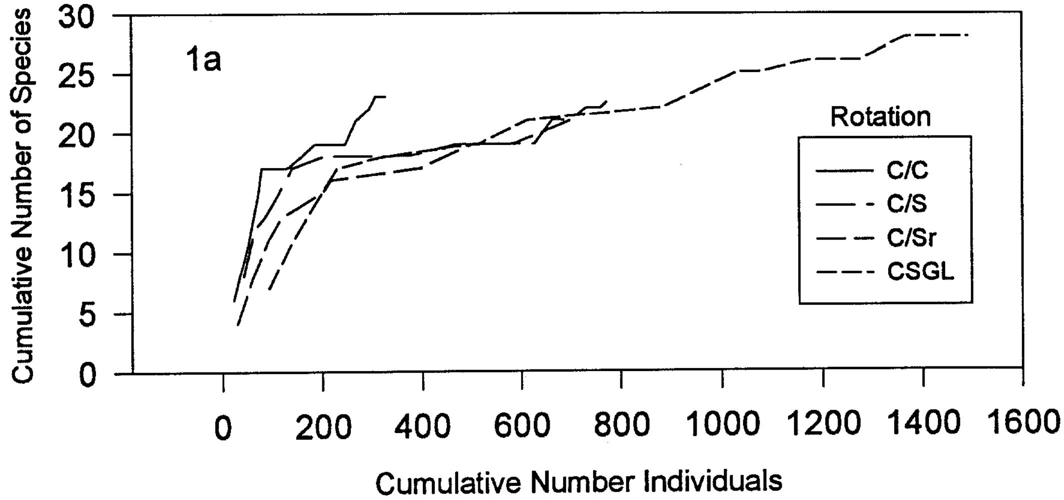

Fig. 1 b. Cumulative # Species Versus Total # Ground Beetles Collected from Four Crops in 1994

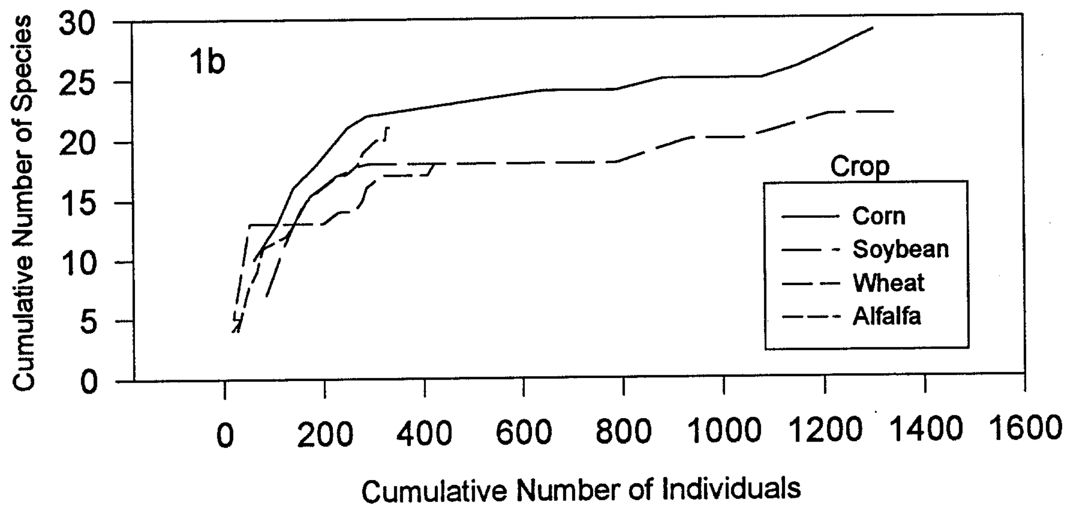

Fig. 1c. Cumulative # Species Versus Total # Ground Beetles Collected from Plots of Three Input Levels in 1994

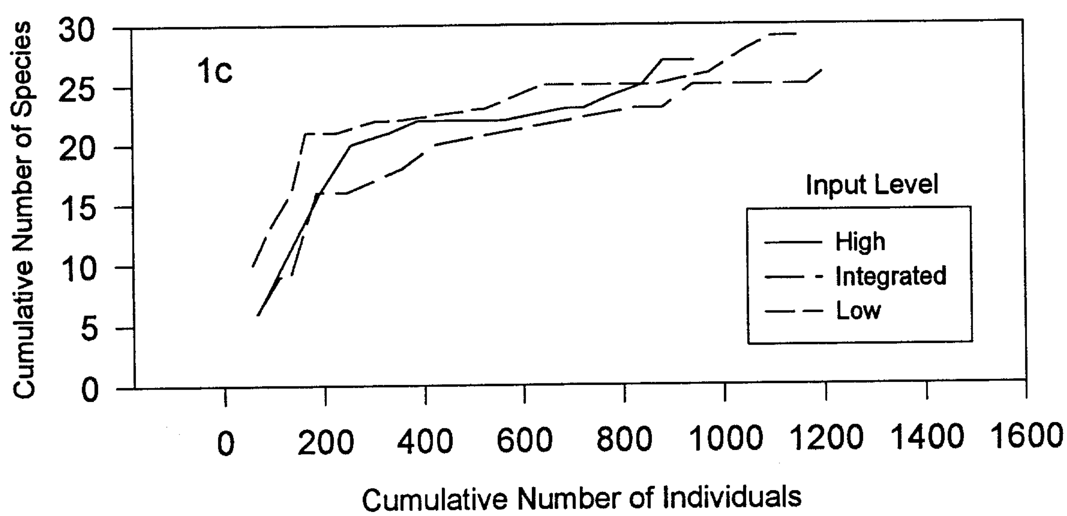

Fig. 2a. Dominant carabid species in plots with three input levels. Dominance calculated as $D=N_D/N_T$

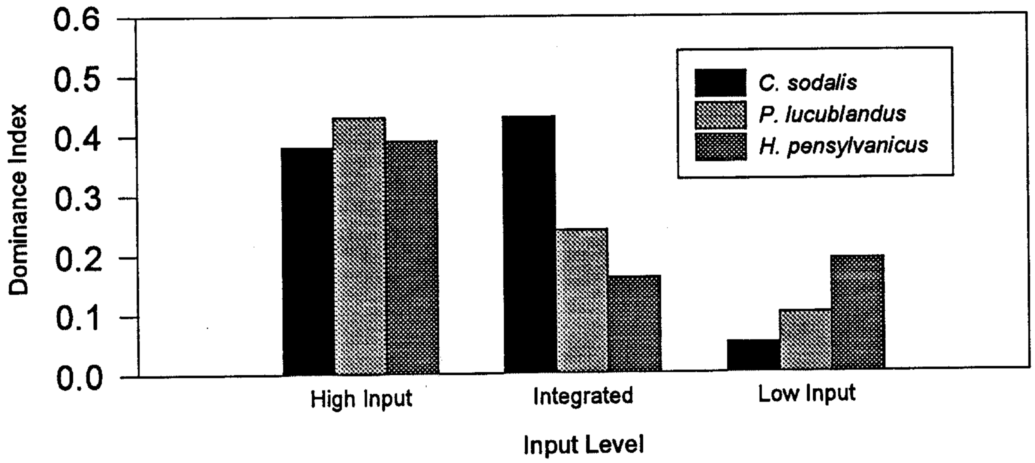

Fig. 2b. Dominant carabid species grouped by crop type. Dominance calculated as $D=N_D/N_T$.

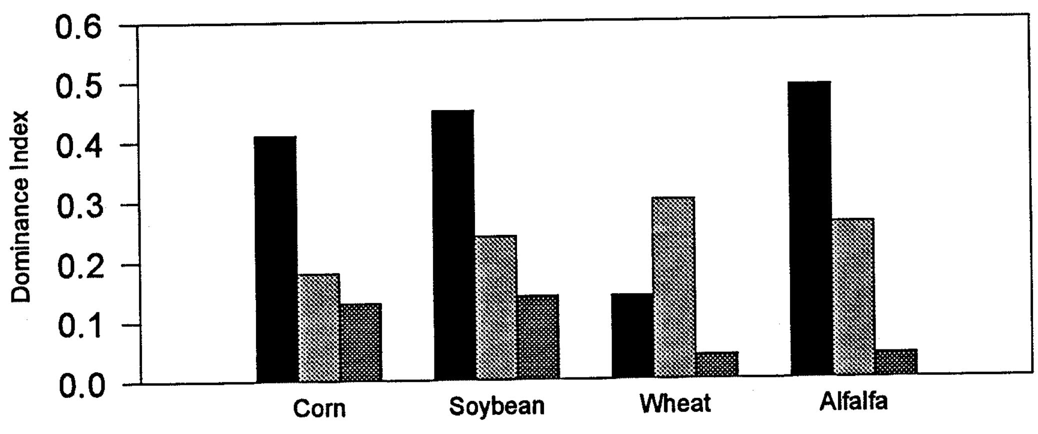

Fig. 2c. Dominant carabid species in four rotational systems. Dominance calculated as $D=N_D/N_T$.